Chapter 8:

Tables and Figures

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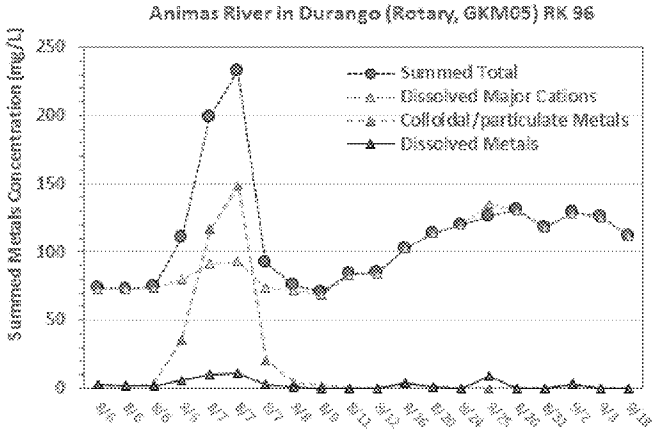


Figure 8-1. Summed total metals concentration in the Animas River at Durango from August 6 to August 26, 2015. The background dissolved concentration is dominated by the major cations (calcium, magnesium, potassium, and sodium).

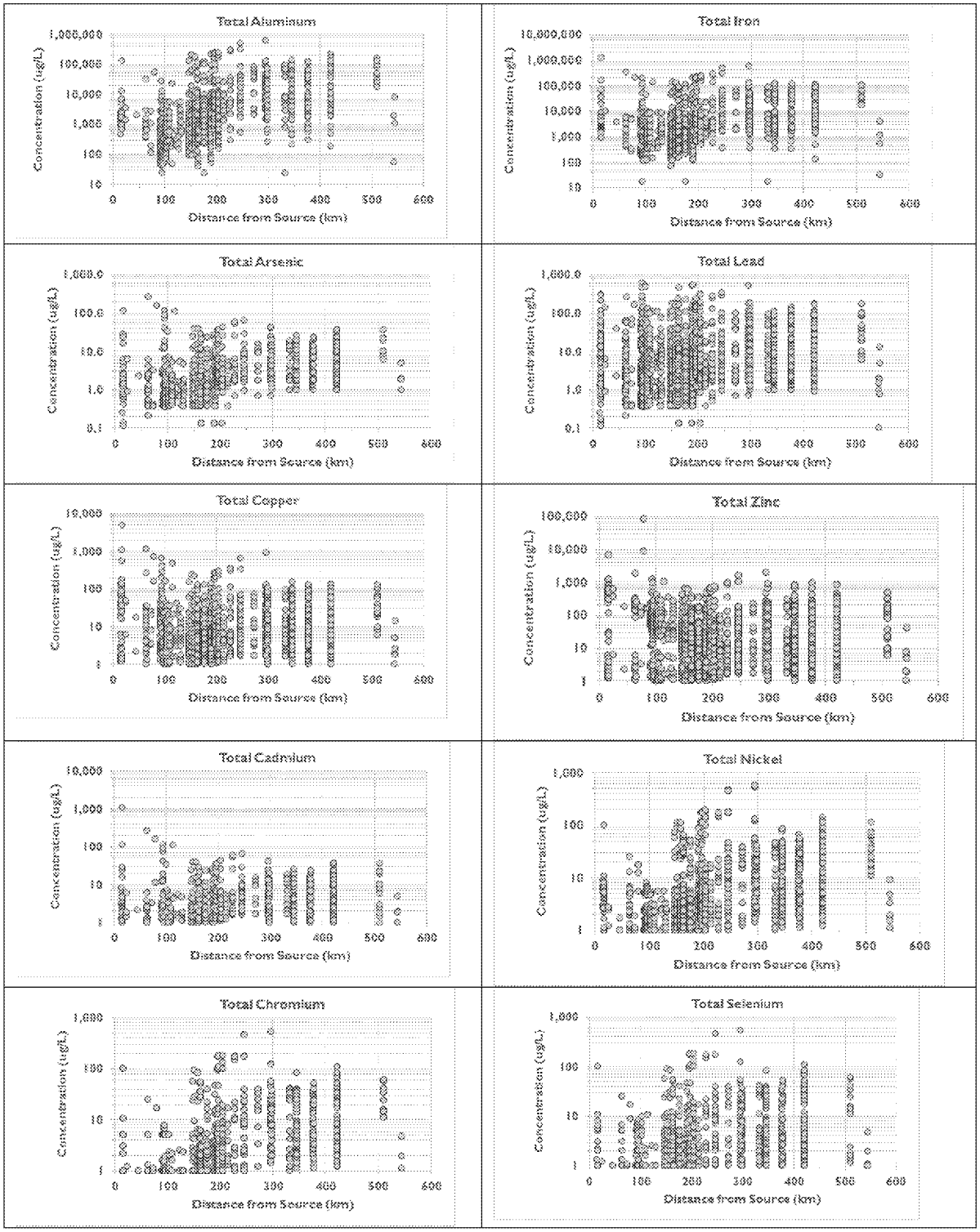


Figure 8-2. Total water concentration (mg/L) for 10 metals in all samples collected in the Animas and San Juan Rivers from August 2015 to June 2016.

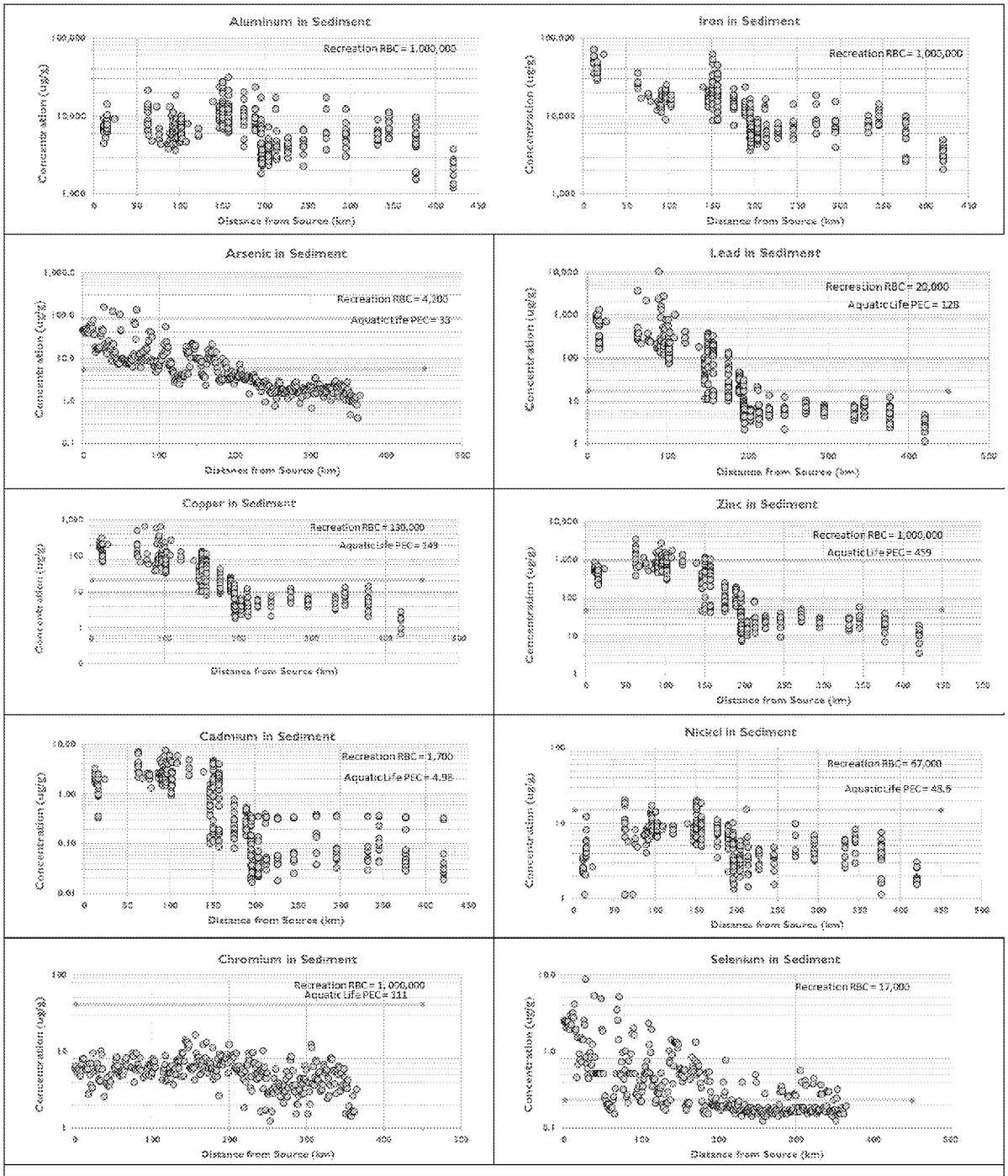


Figure 8-3. Sediment concentration of all samples collected in the Animas and San Juan Rivers from August 2015 to June 2016. Blue lines shown for some metals indicate the mean concentration of that metal in surficial deposits and natural soils in the western United States determined in a synoptic survey by Shacklette *et al.* (1987). This reference provides perspective on the wide range of metals in river sediments within this broad geographic area encompassed in the Animas and San Juan Rivers that was affected by the Gold King release.

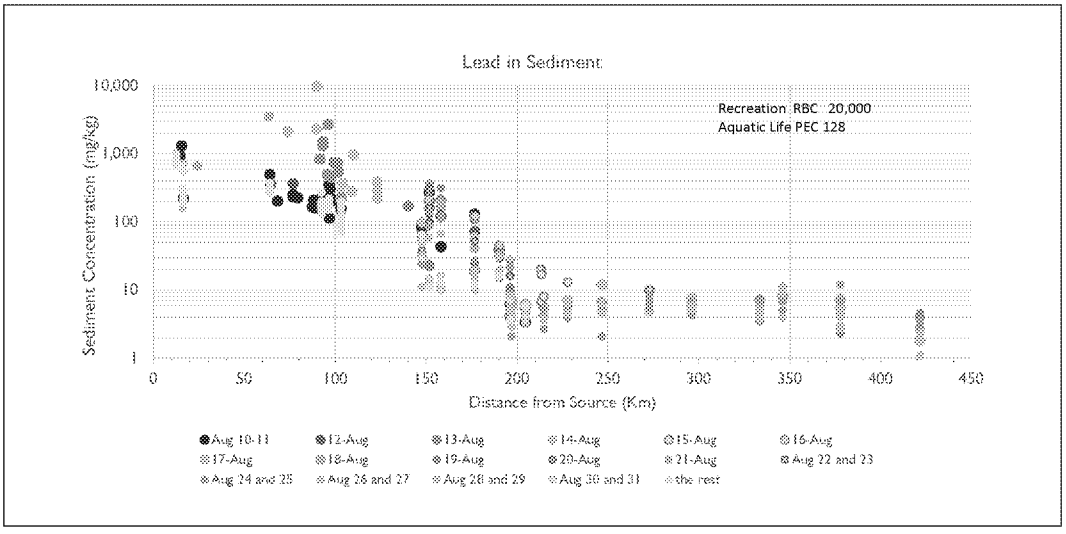


Figure 8-4. Sediment lead concentrations in all samples collected during August 2015 in the Animas and San Juan River project area. Data are color=coded by sampling data to identify any patterns within the immediate period after the Gold King release. The highest concentrations were observed in the Animas River between RK 64 and RK 100, identified in plume modeling as the length where most of the Gold King mass was deposited.

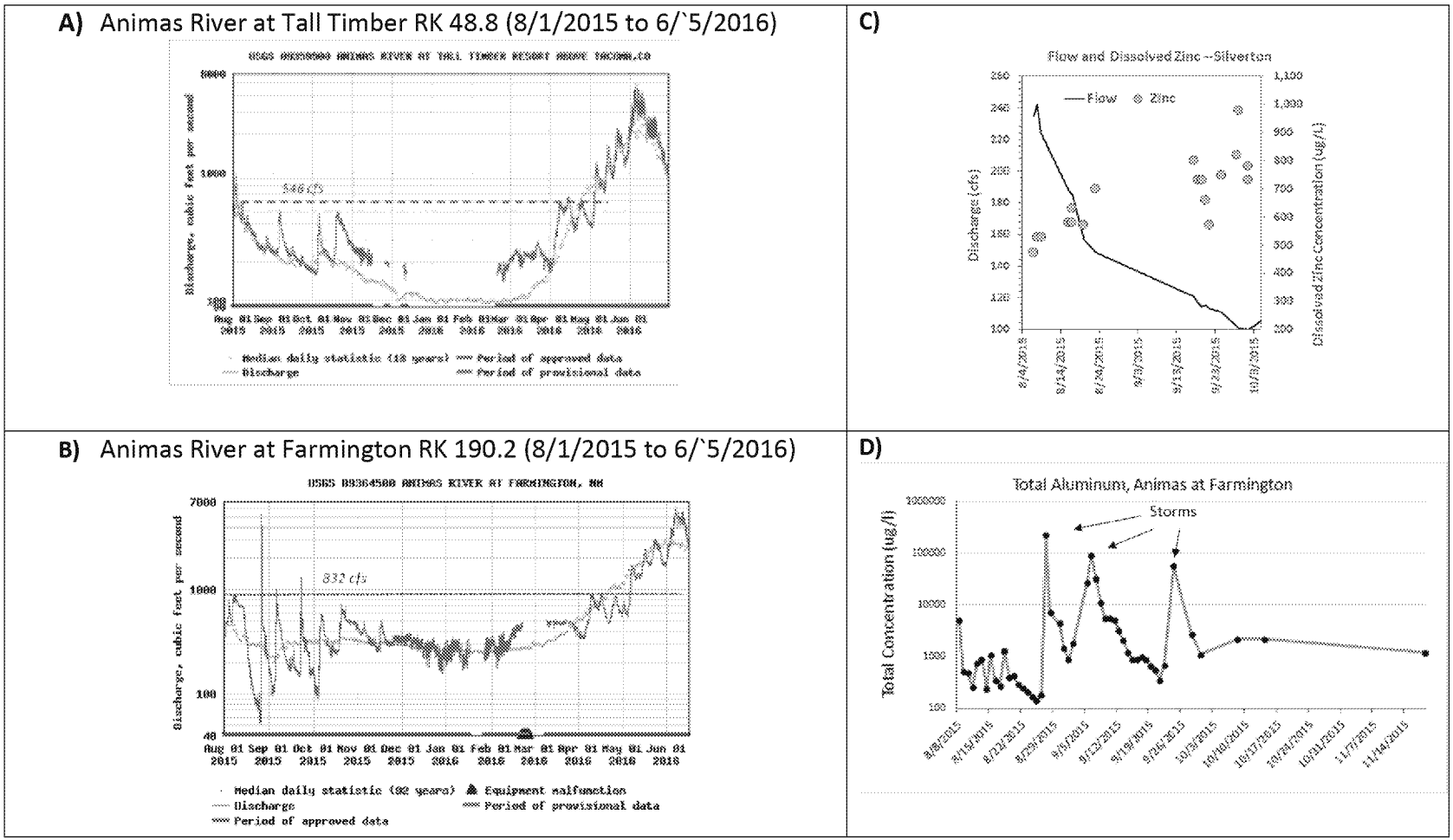


Figure 8-5. Hydrographs of the Animas River at USGS stations at Tall Timber in the upper Animas at RK 48.8 (A) and at Farmington in the lower Animas at RK 190.2 from August 1, 2015 to June 15, 2016. (C) Example of relationship between flow during a low flow period in the hydrograph and dissolved metal concentrations. (D) Example of high flow effects on total metals (Al) during three storms at the Animas Farmington gage (B) in the fall of 2015.

Table 8-1. Data sources and number of samples (D=dissolved, T=total) for pre-event metal concentrations in surface water samples.

Data Source	Cement Creek	Animas River					San Juan River
		Silverton	Baker's Bridge	Durango	South. Ute Res.	Farmington	
EPA Superfund (2012-2015)	13 D, 13 T	130 D, 40 T	5 D				
EPA STORET (2009-2014)				165 D, 148 T			120 D
Southern Ute Nation (2002-2014)					25 D, 23 T		
USGS (1995-2010)						12 D	116 D
Navajo Nation (2011-2015)							30 D

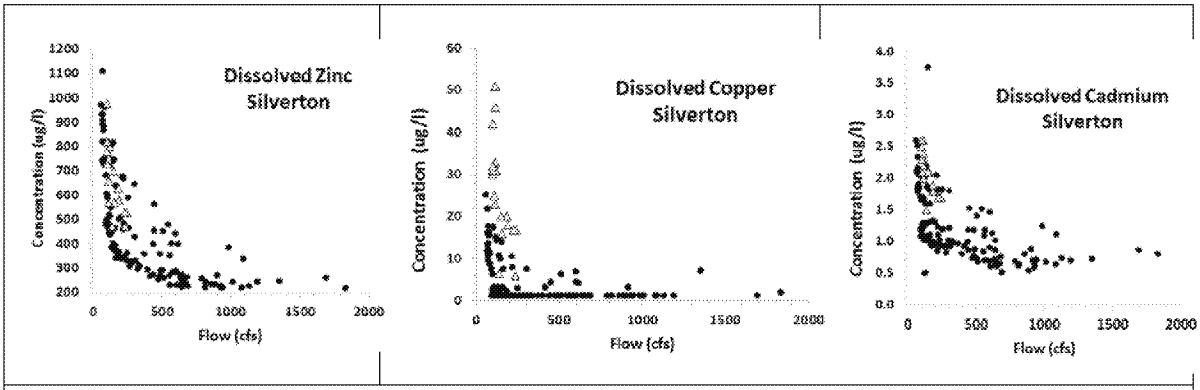


Figure 8-6. Dissolved metals concentrations at Silverton (and other sites) show a strong inverse relationship to streamflow. Some post-event dissolved metal concentrations (yellow triangles) appear elevated relative to pre-event samples (black circles). Apparent post-event increases in concentration may be due to prevailing flow when samples were collected. Statistical analyses (pre-event versus post-event) limit samples included in comparisons to those taken within a similar range of streamflow.

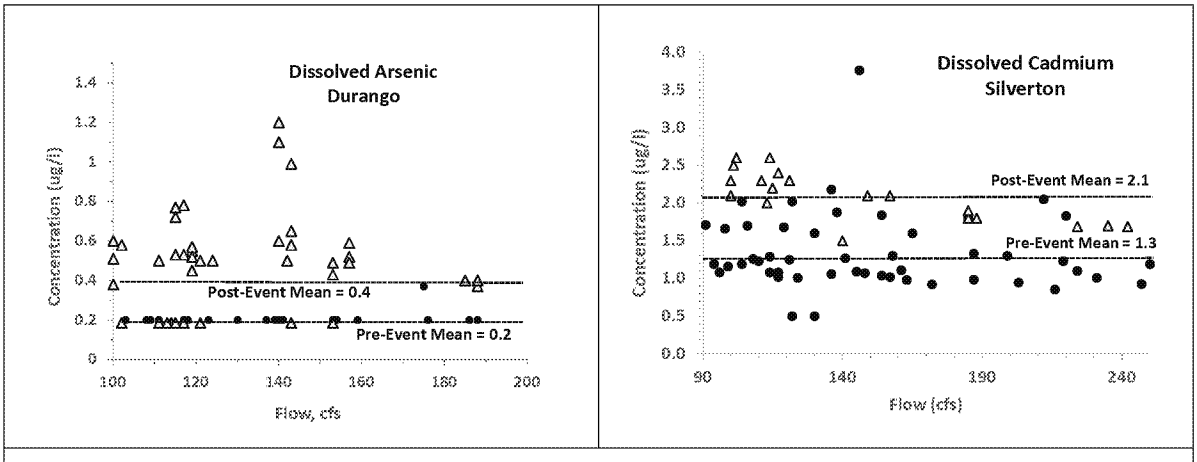


Figure 8-7. Illustration of flow-restricted statistical comparisons between pre-event (black circles) and post-event (yellow triangles) metal concentrations. Mean values for the pre-event and post-event samples are shown. Pre-event samples were screened according to flow, and all post-event samples within the same range were selected for testing. Pre-event and post-event concentration data were statistically compared using a parametric Student's t-test (assuming unequal variance in the two samples) and a non-parametric Wilcoxon rank sum test. Concentrations were logged (base 10) prior to testing.

Post > Pre	Both p-values < 0.05
Post > Pre	One p-value < 0.05
Post = Pre	Neither p-value < 0.05
Post < Pre	One p-value < 0.05
Post < Pre	Both p-values < 0.05

Figure 8-8. Color coding of statistical test results in tables presenting comparisons of pre- and post- Gold King release metals concentrations. Statistical test comparison p-values are coded according to the scheme shown. Post-event means can increase or decrease relative to pre-event samples.

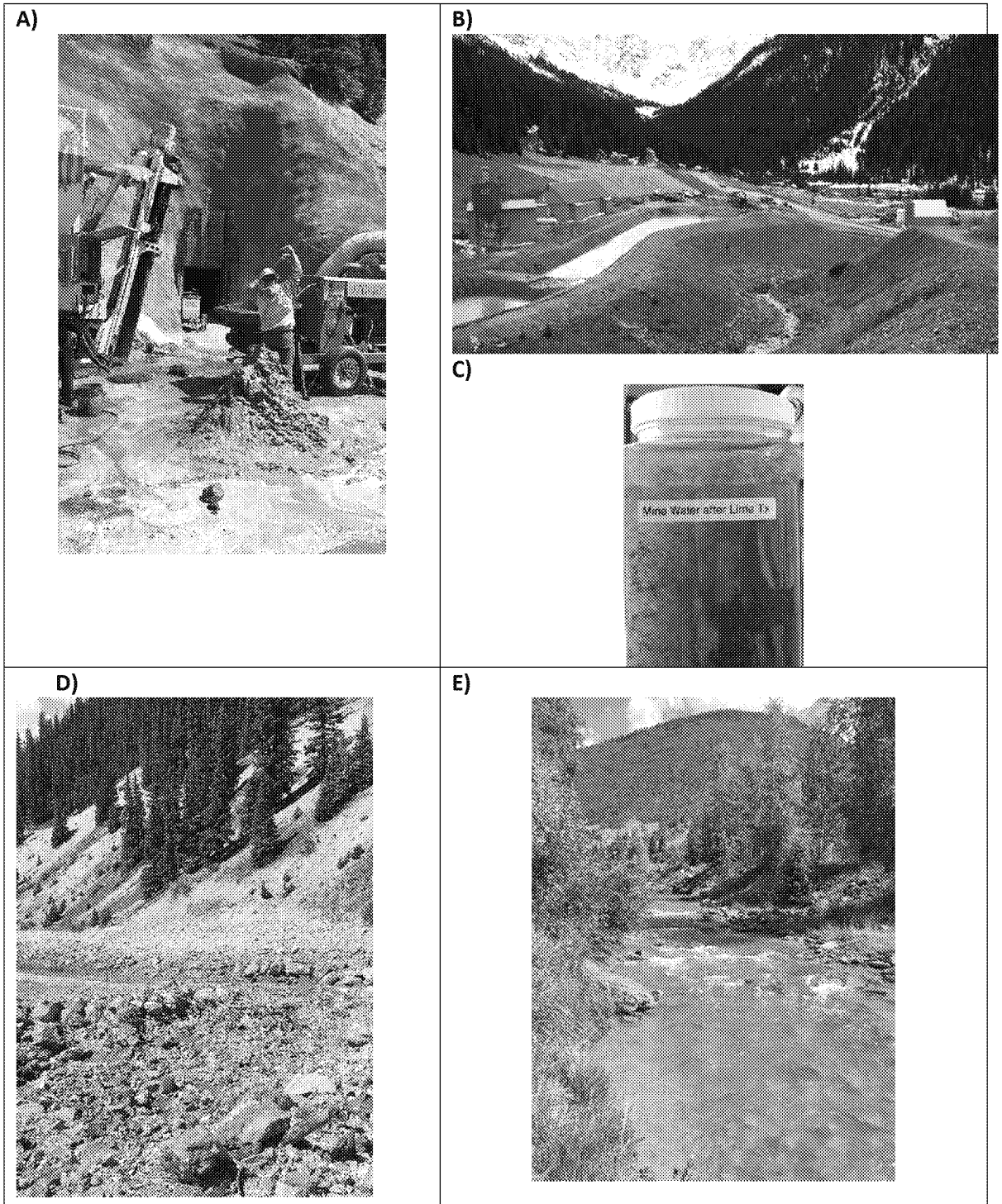


Figure 8-9. (A) Gold King mine entrance August 2016; (B) Gold King setting ponds and Gladstone Water Treatment Plain (from EPA 2016); (C) Treated Gold King effluent; (D) stabilized North Fork Cement Creek below mine, (E) Cement Creek in Silverton.

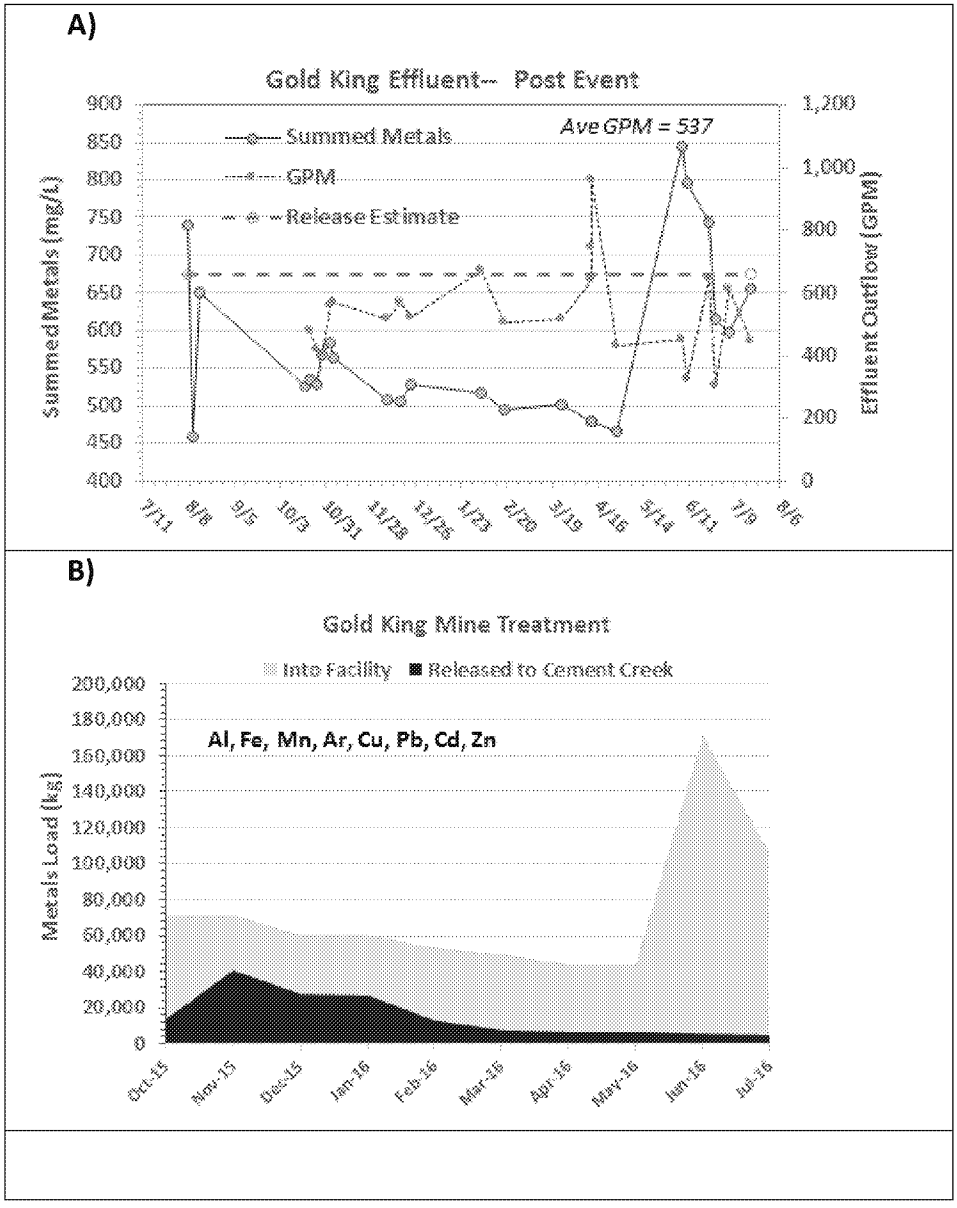


Figure 8-10. (A) Weekly statistics on rate of inflow of effluent and total metals concentrations received at the Gladstone treatment facility from the Gold King Mine. (B) Treatment efficiency of Gold King mine effluent shown as inflow of metals to mass of metals released to Cement Creek.

Table 8-2. Gold King Mine treatment facility efficacy in removing metals from mine influent before release to Cement Creek. Data compiled monthly by contractors at the facility.

		Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16
Aluminum	Into Facility, kg	9,185	9,526	7,862	8,165	6,577	6,350	5,897	5,897	26,422	17,010
	Released to Cement Creek	1,826	5,443	2,759	2,875	530	91	88	88	425	531
Iron	Into Facility, kg	38,556	38,556	32,961	33,566	28,577	25,855	22,907	22,907	115,667	65,772
	Released to Cement Creek	4,956	18,597	11,959	11,014	1,991	181	209	209	877	435
Manganese	Into Facility, kg	12,701	13,381	11,491	10,886	10,433	10,433	8,845	8,845	8,278	10,660
	Released to Cement Creek	5,273	11,113	8,892	8,779	9,866	7,258	6,237	6,237	4,037	3,810
Arsenic	Into Facility, kg	13	13	11	10	10	9	8	8	82	31
	Released to Cement Creek	1	4	3	3	1	0	0	0	1	0
Copper	Into Facility, kg	2,064	2,019	1,663	1,633	1,542	1,452	1,293	1,293	4,366	2,994
	Released to Cement Creek	332	1,157	654	973	105	12	13	13	33	23
Lead	Into Facility, kg	14	13	12	12	12	10	9	9	11	13
	Released to Cement Creek	2	10	3	3	1	0	0	0	0	0
Cadmium	Into Facility, kg	23	25	21	21	19	18	16	16	62	37
	Released to Cement Creek	5	15	12	9	3	2	2	2	2	2
Zinc	Into Facility, kg	8,392	8,165	6,653	6,350	6,124	5,897	4,990	4,990	16,670	9,979
	Released to Cement Creek	1,344	4,513	3,461	3,395	491	118	156	156	181	159
Summed	Into Facility, kg	70,947	71,697	60,674	60,644	53,292	50,024	43,964	43,964	171,559	106,495
	Released to Cement Creek	13,738	40,853	27,743	27,051	12,988	7,662	6,706	6,706	5,557	4,961

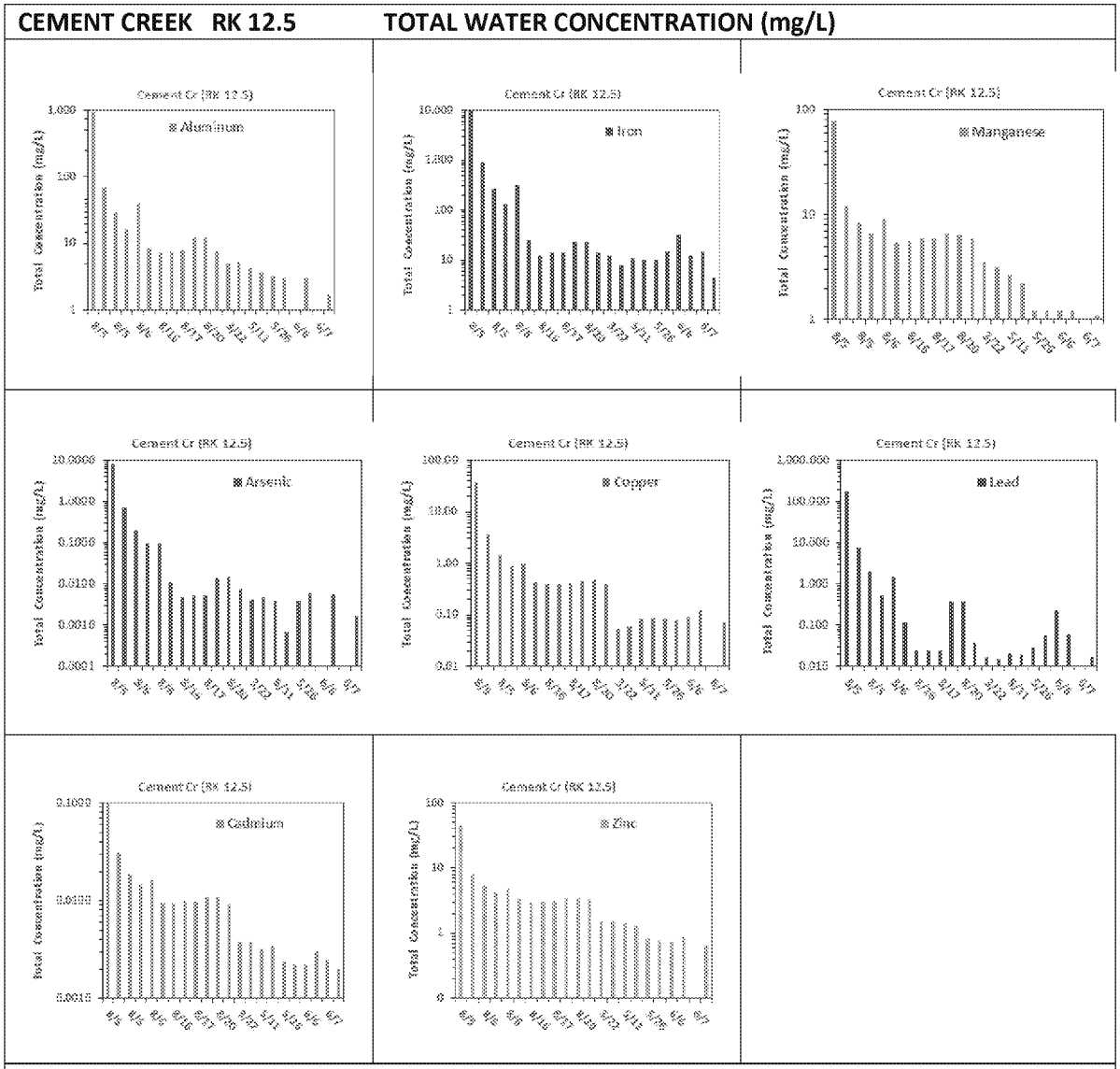


Figure 8-11. Total water concentration of samples collected at Cement Creek (RK 12.5) from 8/5/2015 and 6/30/2016 sequenced in time in mg/L. Data was collected between. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. 2016 snowmelt data are included where available. The Gold King plume was clearly evident at many locations but sampling began after the plume. The data presentation is intended to emphasize post release trends.

Table 8-3. Results of statistical analyses comparing pre-event to post-event dissolved and total metal concentrations near the mouth of Cement Creek. Post-event samples were collected from 8/8/2015 to 10/1/2015, when flow varied from 16-27 cfs in Cement Creek. Concentrations were logged (base 10) prior to testing. All available sediment measurements are included in tests.

Dissolved Concentration CEMENT CREEK

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Icoxon p-value
Aluminum	7050	291	7600	76	0.15	0.016
Cadmium	5.7	0.3	9.7	0.2	0.00036	0.0001
Copper	106	15	388	14	0.0018	0.0001
Iron	8700	990	7900	588	0.54	0.31
Lead	15	1.8	18	4.7	0.52	0.97
Manganese	4700	221	6300	111	0.0037	0.0001
Zinc	2400	79	3500	68	0.0002	0.0001
n=	6		17			

Total Concentation CEMENT CREEK

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	6600	389	8000	323	0.03	0.003
Cadmium	5.6	0.3	9.5	0.2	0.0001	0.0001
Copper	100	13	370	13	0.00015	0.0001
Iron	9300	854	15200	999	0.012	0.0001
Lead	16	1.5	25	26	0.21	0.42
Manganese	4500	239	6300	127	0.0013	0.0001
Zinc	2300	92	3400	70	0.00015	0.0001
n=	7		14			

Bed Sediment Concentration CEMENT CREEK

Metal	Pre-Event Sample (mg/kg)	Fall 2015 Average (mg/kg)	SE	z-score
Aluminum	5310	6626	216	-1.4
Cadmium	0.595	2.1	0.07	-4.4
Copper	55.6	193	4.6	-6.4
Iron	143000	50970	1637	11.9
Lead	282	803	21	-5.3
Manganese	478	581	16	-1.4
Zinc	666	557	19	1.2
n=	1	22		

Bed Sediment concentration—During Snowmelt 2016 Cement Creek

Metal	Pre-Event Sample (mg/kg)	Snowmelt 2016 Average (mg/kg)	SE	z-score
Aluminum	5310	7627	281	-3.0
Cadmium	0.595	1.6	0.32	-1.4
Copper	55.6	101	7.2	-2.3
Iron	143000	74940	5846	4.0
Lead	282	380	25	-1.5
Manganese	478	633	53	-1.1
Zinc	666	540	83	0.4
n=	1	8		

Animas River RK 16.4 (below Silverton) TOTAL WATER CONCENTRATION (mg/L)

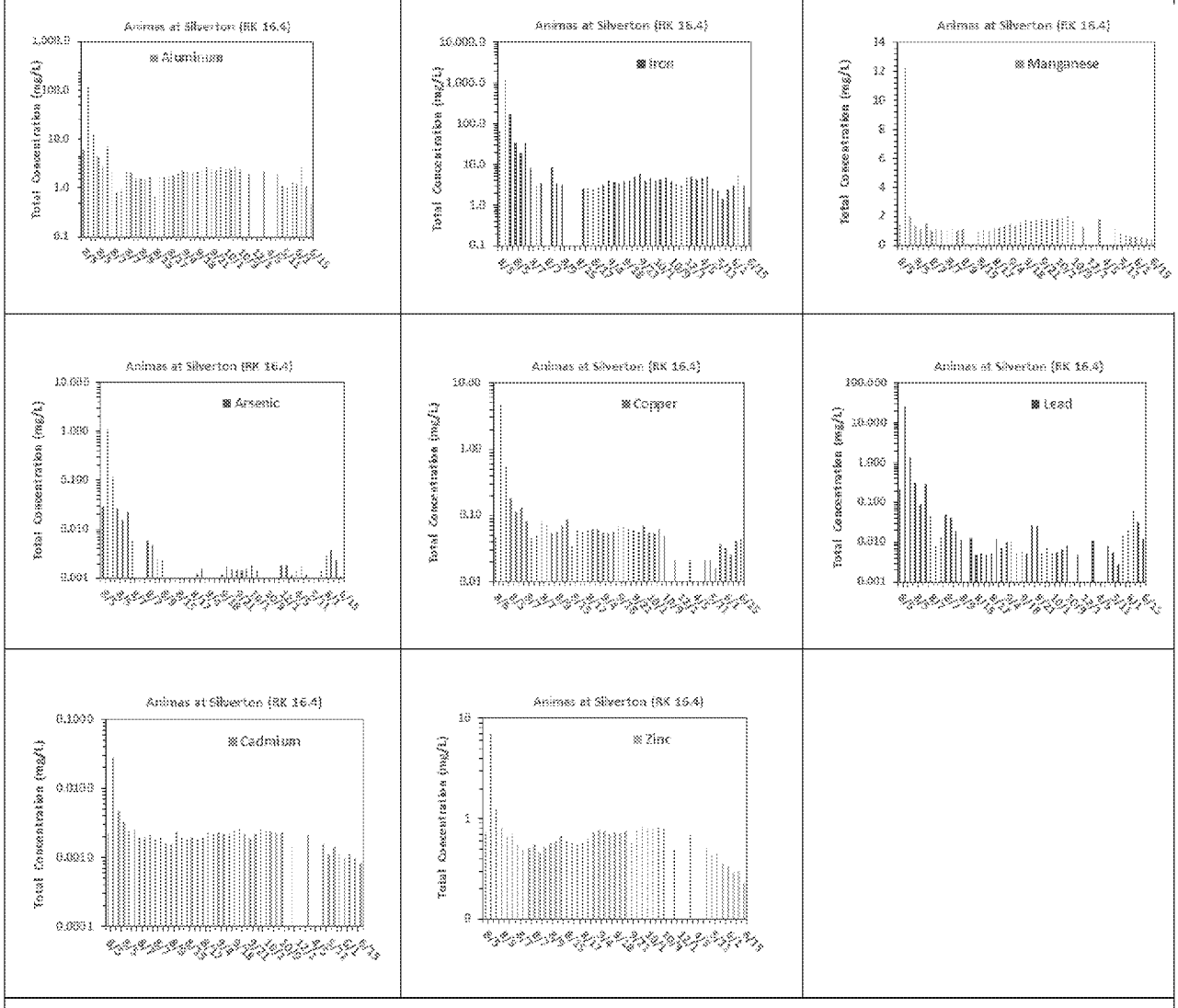


Figure 8-12. Total water concentration of samples collected in the Animas River at RK 16.4 (below Silverton) from 8/5/2015 and 6/30/2016 sequenced in time in mg/L. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. 2016 snowmelt data are included where available. The Gold King plume was clearly evident at many locations but sampling began after the plume. The data presentation is intended to emphasize post release trends.

Table 8-4. Results of statistical analyses comparing pre-event to post-event dissolved and total metal concentrations on the Animas River at RK 16.4 (below Silverton, CO). Post-event samples. Data include samples were collected at flow between 100-250 cfs. Concentrations were logged (base 10) prior to testing.

Dissolved Concentration	Animas River at Silverton					
Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	46	22	160	107	0.0016	0.0014
Cadmium	1.3	0.09	2.1	0.08	<0.0001	<0.0001
Copper	2.7	0.75	22.3	2.8	<0.0001	<0.0001
Iron	1406	75	1509	220	0.7	0.75
Lead	0.29	0.04	0.37	0.85	Non-Detection Bias*	
Manganese	1419	69	1471	69	0.7	0.79
Zinc	490	23	651	31	<0.0001	<0.0001
n=	41		19			

Total Concentration	Animas River below Silverton (A72)					
Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	2207	660	2053	88	0.68	0.11
Cadmium	1.94	0.17	2.09	0.08	0.27	0.24
Copper	26	2.8	57	2.6	0.0001	0.00005
Iron	3038	303	3746	354	0.05	0.04
Lead	10.3	29.2	8.6	2.4	0.70	0.80
Manganese	1440	129	1449	71	0.53	0.63
Zinc	654	40	645	27	0.43	0.60
n=	11		18			

Bed Sediment Concentration	Fall 2015		Animas River below Silverton (A72)			
Metal	Pre-Event (mg/kg)	SE	Fall 2015 (mg/kg)	SE	t-test p-value	Wilcoxon p-value
Aluminum	14783	2246	8022	474	0.05	0.002
Cadmium	1.8	0.35	1.1	0.15	0.07	0.11
Copper	128	17	121	15	0.83	0.69
Iron	53455	5688	37866	1471	0.06	0.008
Lead	442	49	310	35	0.08	0.33
Manganese	1793	413	1240	100	0.24	0.18
Zinc	603	79	392	28	0.07	0.03
n=	5		22			

Bed Sediment Concentration	2016 Snowmelt		Animas River below Silverton (A72)			
Metal	Pre-Event (mg/kg)	SE	Snowmelt 2016 (mg/kg)	SE	t-test p-value	Wilcoxon p-value
Aluminum	14783	2246	11100	1284	0.29	0.51
Cadmium	1.8	0.35	1.2	0.58	0.27	0.53
Copper	128	17	100	65	0.5	0.65
Iron	53455	5688	56600	9478	0.74	0.92
Lead	442	49	408	759	0.78	0.64
Manganese	1793	413	1670	484	0.74	0.92
Zinc	603	79	455	116	0.27	0.53
n=	5		8			

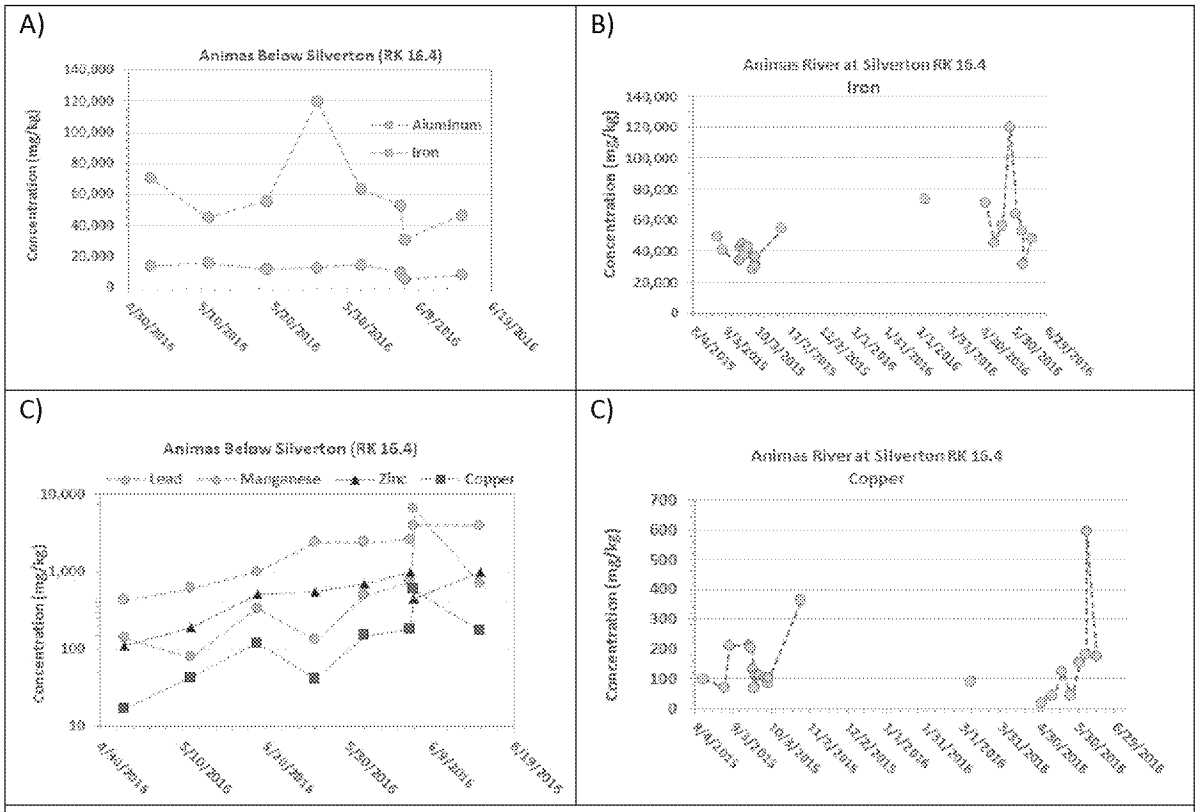


Figure 8-13. Time sequence of sediment concentrations (mg/kg) in the Animas River at RK 16.4 (below Silverton, A72). (A) Aluminum and iron during snowmelt from April through June 2016; (B) Iron from August 5 through June 2016. Iron is shown because it was the major component of the Gold King Mass; (C) Trace metals during during snowmelt from April through June 2016; and (D) Copper from August 5 thorugh June 2016.

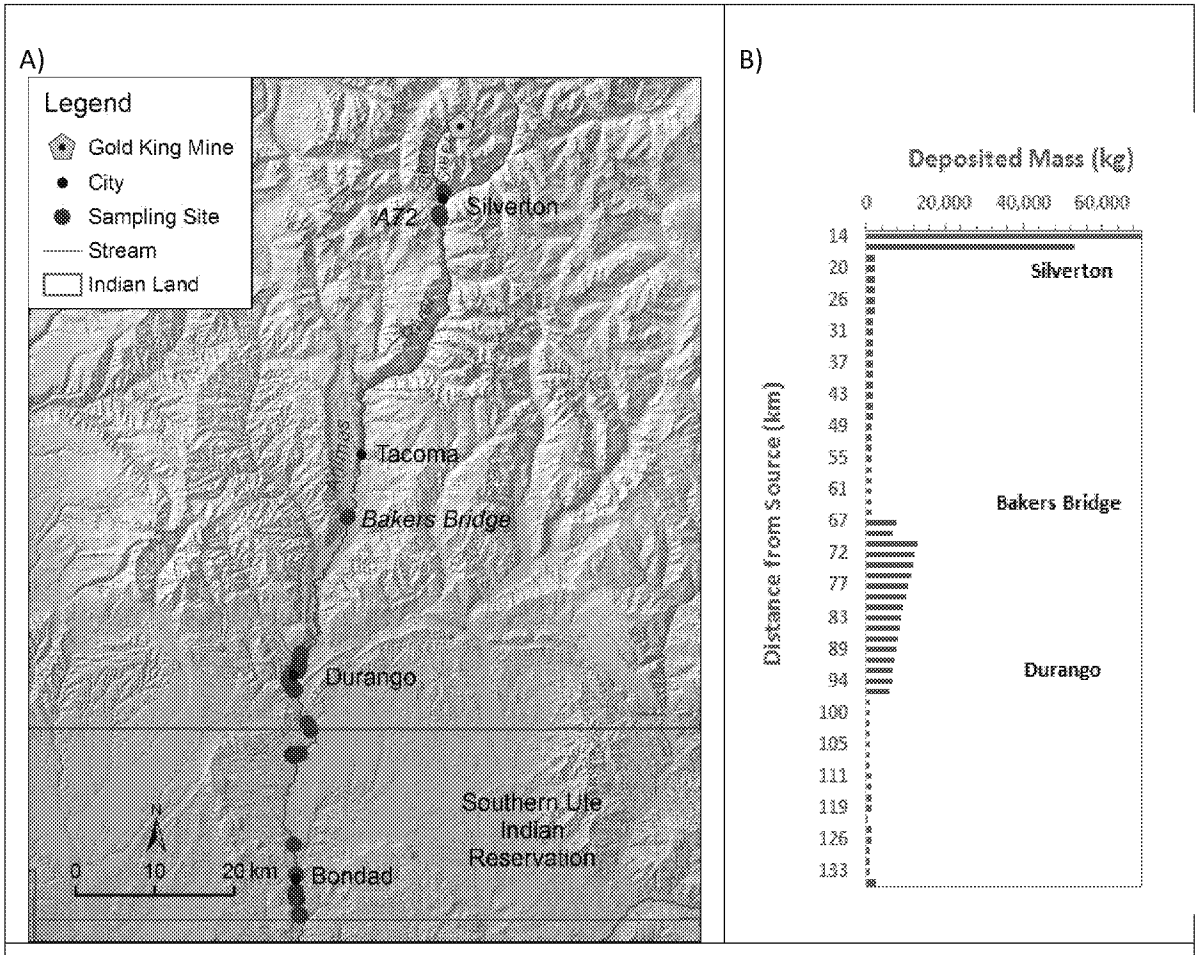


Figure 8-14. Middle reach of the Animas River from the headwaters including Cement Creek to approximately RK 132 near the Colorado-New Mexico border (A). Sampling locations are shown as red dots. Mass deposits estimated with WASP modeling in approximately 2-km segments through the middle Animas reach as an indicator of localized deposition zones (B).

Bakers Bridge

Animas River RK 64.0 Bakers Bridge TOTAL WATER CONCENTRATION (mg/L)

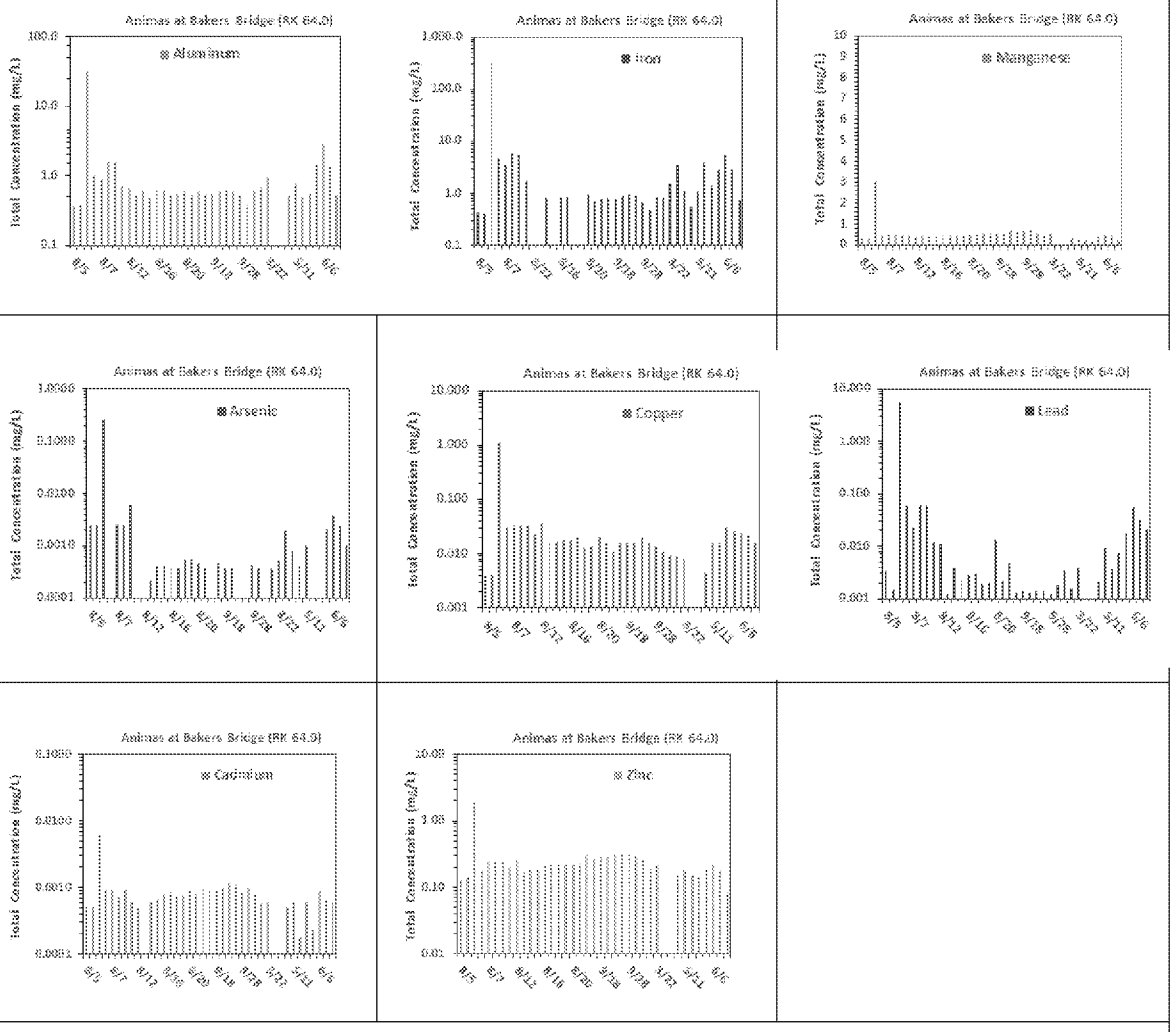


Figure 8-15. Total water concentration of samples collected from the Animas River at RK 64.0 (Bakers Bridge) from 8/5/2015 and 6/30/2016 sequenced in time in mg/L. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. 2016 snowmelt data are included where available. The Gold King plume was clearly evident at many locations but sampling began after the plume. The data presentation is intended to emphasize post release trends.

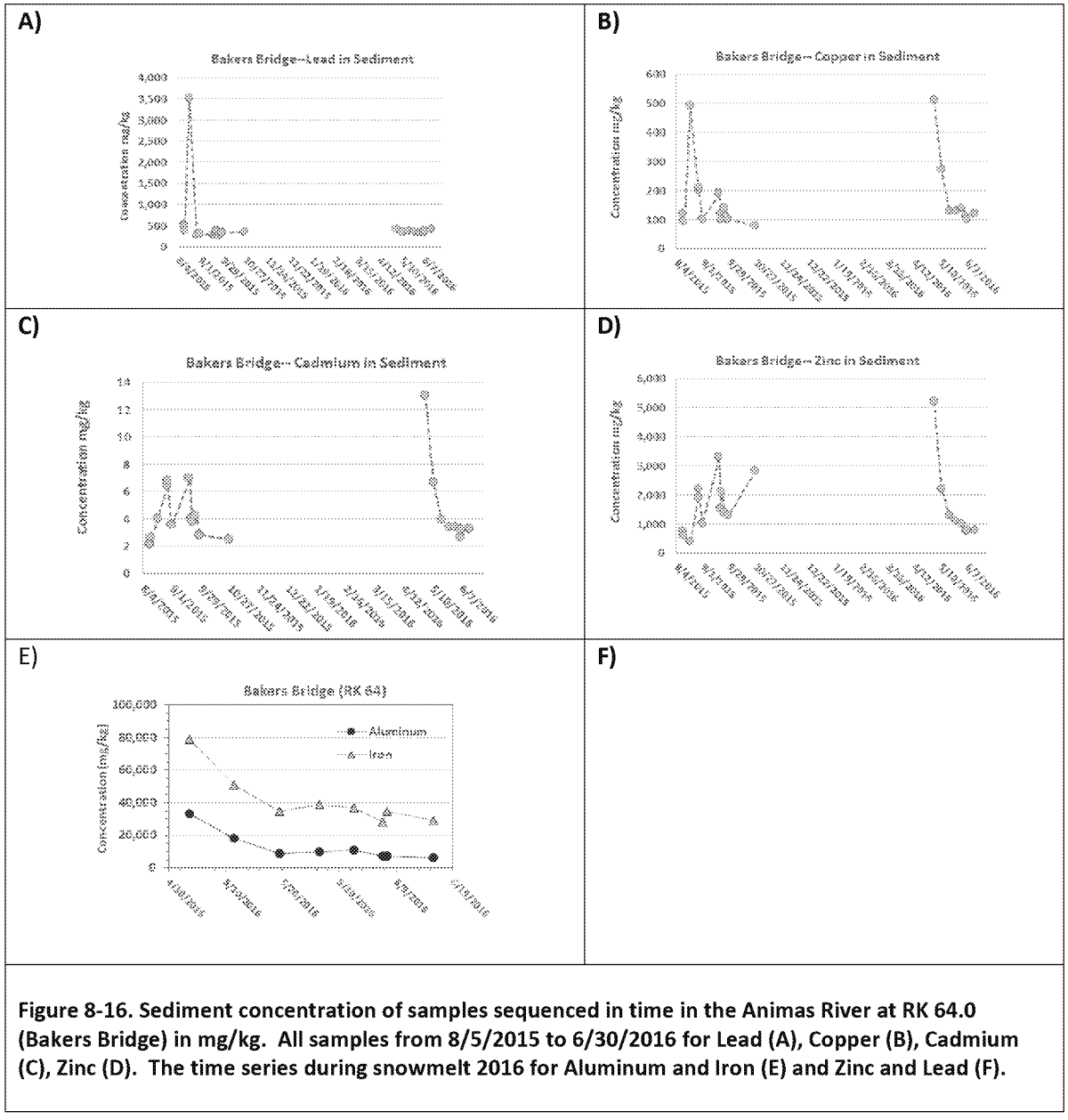


Figure 8-16. Sediment concentration of samples sequenced in time in the Animas River at RK 64.0 (Bakers Bridge) in mg/kg. All samples from 8/5/2015 to 6/30/2016 for Lead (A), Copper (B), Cadmium (C), Zinc (D). The time series during snowmelt 2016 for Aluminum and Iron (E) and Zinc and Lead (F).

Table 8-5. Results of statistical tests on streambed sediment metal concentrations on the Animas River at RK 64.0 (Baker's Bridge) for pre-event (n=4) and fall 2015 (n=18) samples. Concentrations were logged prior to testing. Fall 2015 concentrations generally looked lower than pre-event samples, but were not statistically different.

Bed Sediment Concentration			Bakers Bridge (RK 64)			
Metal	Pre-Event (mg/kg)	SE	Fall 2015 (mg/kg)	SE	t-test p-value	Wilcoxon p-value
Aluminum	15,700	7,410	9,500	921	0.70	0.99
Cadmium	8	3.9	4	0.38	0.59	0.62
Copper	170	60	135	22	0.85	0.77
Iron	42,500	10,918	28,500	1,316	0.45	0.16
Lead	300	33	370	177	0.12	0.15
Manganese	5,800	2,608	3,600	415	0.67	0.77
Zinc	3,700	1,668	1,400	205	0.22	0.22
n=	4		18			

Bed Sediment Concentration	2016 Snowmelt		Bakers Bridge (RK 64)			
Metal	Pre-Event (mg/kg)	SE	Snowmelt 2016 (mg/kg)	SE	t-test p-value	Wilcoxon p-value
Aluminum	15,700	7,410	10,800	3,179	0.64	0.83
Cadmium	8	3.9	4	1.2	0.51	0.67
Copper	170	60	160	50	0.85	0.67
Iron	42,500	10,918	39,400	5,895	0.96	0.67
Lead	300	33	350	11	0.13	0.07
Manganese	5,800	2,608	4,200	1,144	0.64	0.67
Zinc	3,700	1,668	1,300	537	0.10	0.07
n=	4		8			

Animas River RK 91 to 100.0 Durango area TOTAL WATER CONCENTRATION (mg/L)

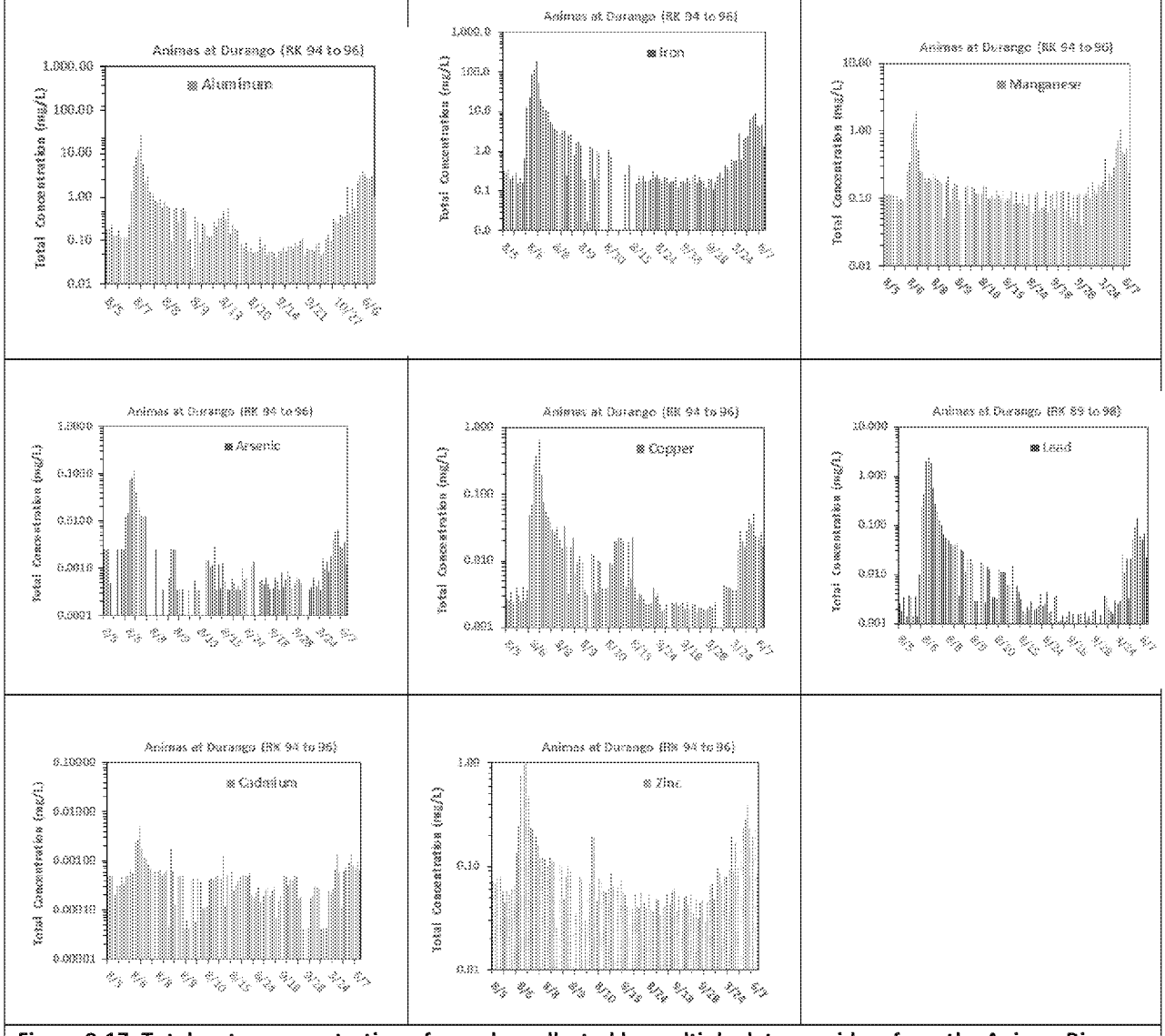


Figure 8-17. Total water concentration of samples collected by multiple data providers from the Animas River from RK 91.8 to 95.8 from 8/5/2015 and 6/30/2016 sequenced in time in mg/L. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. 2016 snowmelt data are included where available. The Gold King plume was clearly evident at many locations but sampling began after the plume. The data presentation is intended to emphasize post release trends.

Table 8-6. Results of statistical analyses comparing pre-event to post-event dissolved and total metal concentrations on the Animas River at RK 95 (Durango, CO). Flow during the post-event sampling period varied from 100-210 cfs. Concentrations were logged (base 10) prior to testing. There were no pre-event sediment samples at this location.

Dissolved Concentration — Animas River at Durango

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	24	2.0	27	4	0.45	0.65
Cadmium	1.00	0.01	0.14	0.02	Non-Detection Bias	
Copper	1.4	0.12	1.9	0.10	Non-Detection Bias	
Iron	21	2.5	33	14	0.06	0.56
Lead	3	0.08	0.34	0.16	Non-Detection Bias	
Manganese	69	6.3	53	5.1	0.02	0.07
Zinc	36	3.0	29	1.9	0.01	0.04
n=	40		57			

Total Concentration — Animas River at Durango

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	152	55	94	13	0.005	0.03
Cadmium	0.25	0.02	0.22	0.03	0.27	0.90
Copper	2.7	0.40	3.0	0.73	0.67	0.90
Iron	301	85	211	9.3	0.017	0.12
Lead	3.7	0.54	2.0	0.33	Non-Detection Bias	
Manganese	102	10	83	4.1	0.02	0.05
Zinc	54	6.1	44	1.6	0.02	0.15
n=	37		57			

Table 8-7. Results of statistical analyses comparing pre-event to post-event dissolved and total metal concentrations at sites at RK 103 to 132 (Southern Ute Indian Tribe Reservation). Sample size varied by metal as not all metals were tested. Flow in the post-event period varied between 250 and 650 cfs. Concentrations were logged (base 10) prior to testing. There were no pre-event sediment samples available at this location.

Dissolved Concentration Southern Ute Indian Reservation

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	36	14	46	4.2	0.41	0.37
Cadmium	0.61	0.24	0.06	0.003	Non-Detection Bias	
Copper	4.3	0.33	1.8	0.22	Non-Detection Bias	
Iron	40.8	12	50.8	13	0.37	0.43
Lead	7.8	1.9	0.39	0.09	Non-Detection Bias	
Manganese	27.0	7.5	20.0	3.4	0.32	0.19
Zinc	8.3	40	10.0	0.96	Non-Detection Bias	
n (varies with metal) =	13-25		30-34			

Total Concentration Southern Ute Indian Reservation

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	387	335	280	49	0.30	0.64
Cadmium	1.4	0.29	0.15	0.19	Non-Detection Bias	
Copper	5.0	0.82	3.9	0.39	0.18	0.05
Iron	435.6	237	543.1	93	0.42	0.18
Lead	13.0	2.2	5.6	1.6	Non-Detection Bias	
Manganese	75.6	4.6	79.7	5.9	0.72	0.27
Zinc	25.2	3.3	27.8	2.2	0.62	0.69
n (varies with metal) =	15-23		30-34			

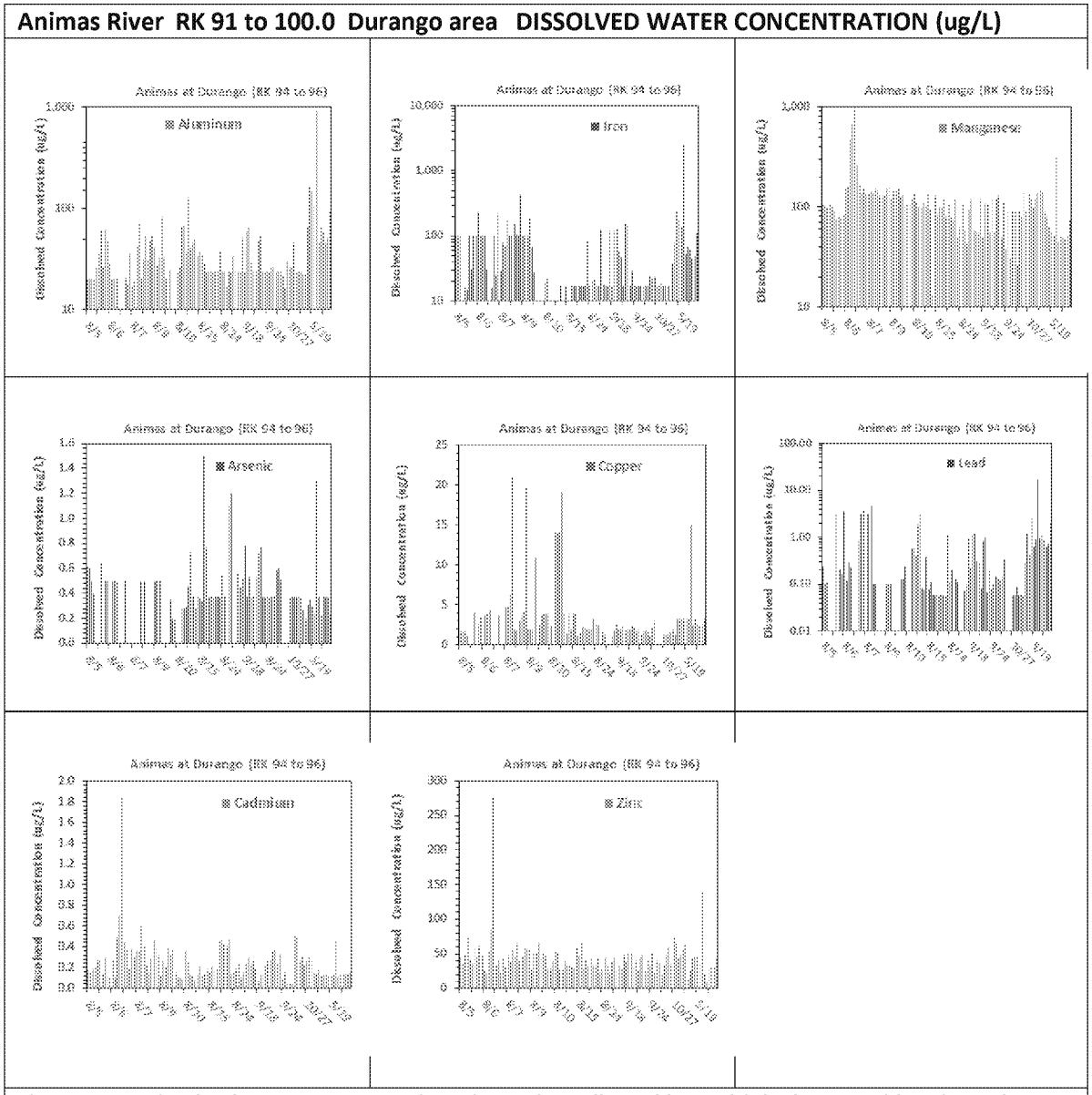


Figure 8-18. Dissolved water concentration of samples collected by multiple data providers from the Animas River from RK 91.8 to 95.8 from 8/5/2015 and 6/30/2016 sequenced in time in ug/L. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. 2016 snowmelt data are included where available. The Gold King plume was clearly evident at many locations but sampling began after the plume. The data presentation is intended to emphasize post release trends.

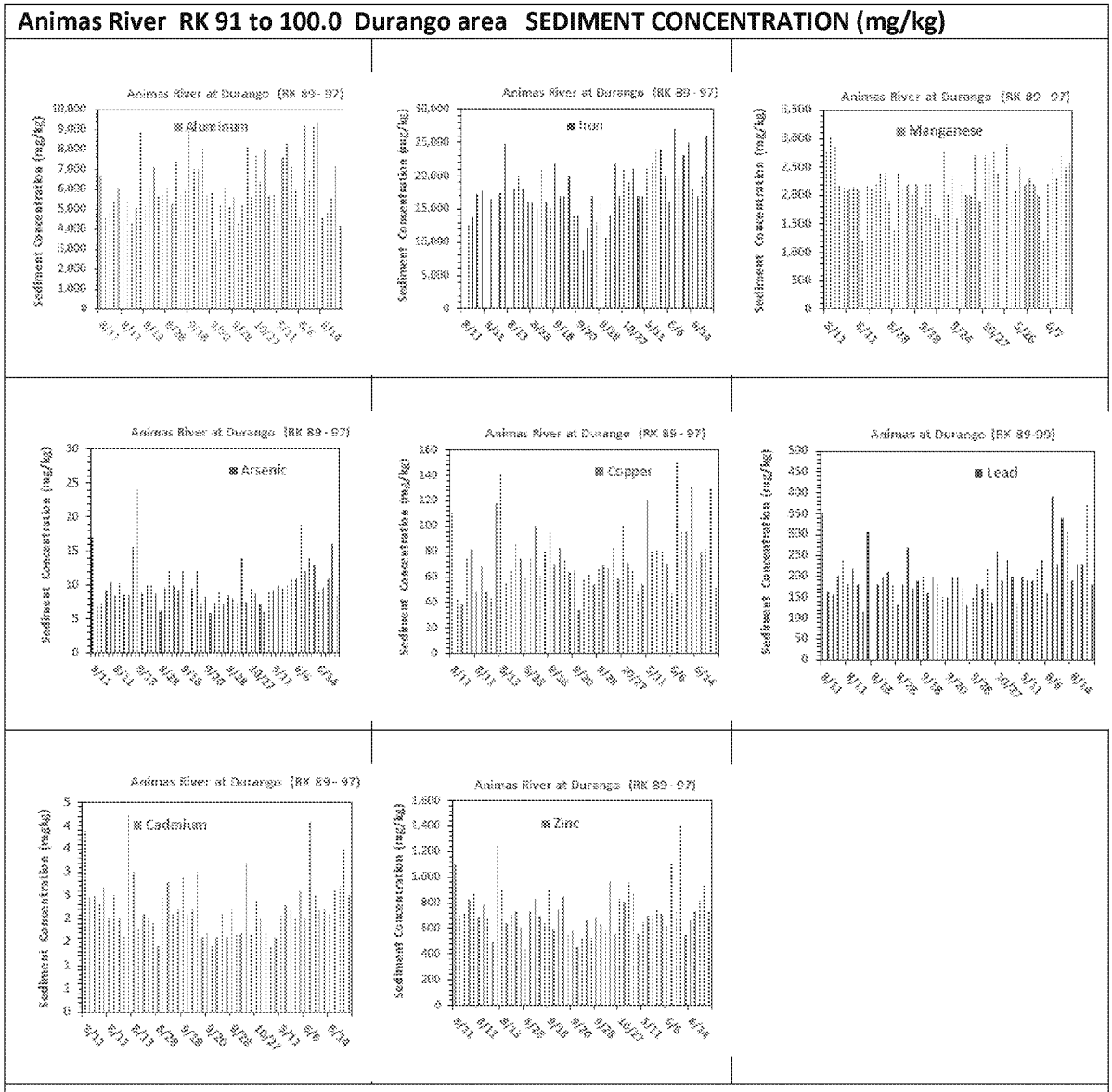


Figure 8-19. Sediment concentration of samples collected from the Animas River between RK 89.9 and RK 98 from 8/5/2015 and 6/30/2016 sequenced in time in mg/kg. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. 2016 snowmelt data are included. The data presentation is intended to emphasize post release trends.

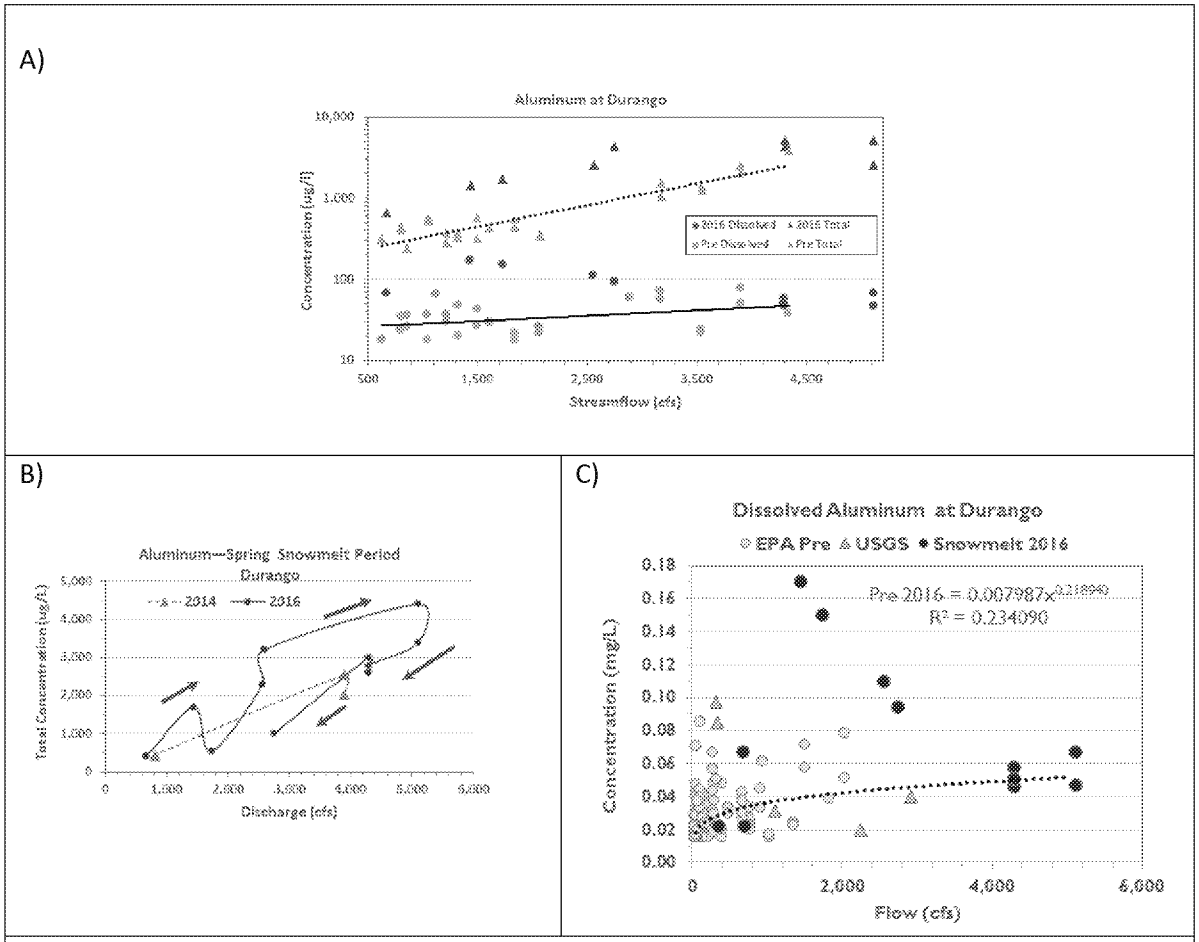


Figure 8-20. Characteristics of metals concentrations during snowmelt hydrographs comparing historic data with 2016 snowmelt. (A) Relationship between total and dissolved concentrations of Aluminum; (B) Demonstration of hysterisis in total aluminum concentration of sequential samples in 2014 and 2016; (C) Relationship between flow and dissolved Aluminum highlighting post Gold King (gray), historic USGS (triangles) and 2016 (red) samples.

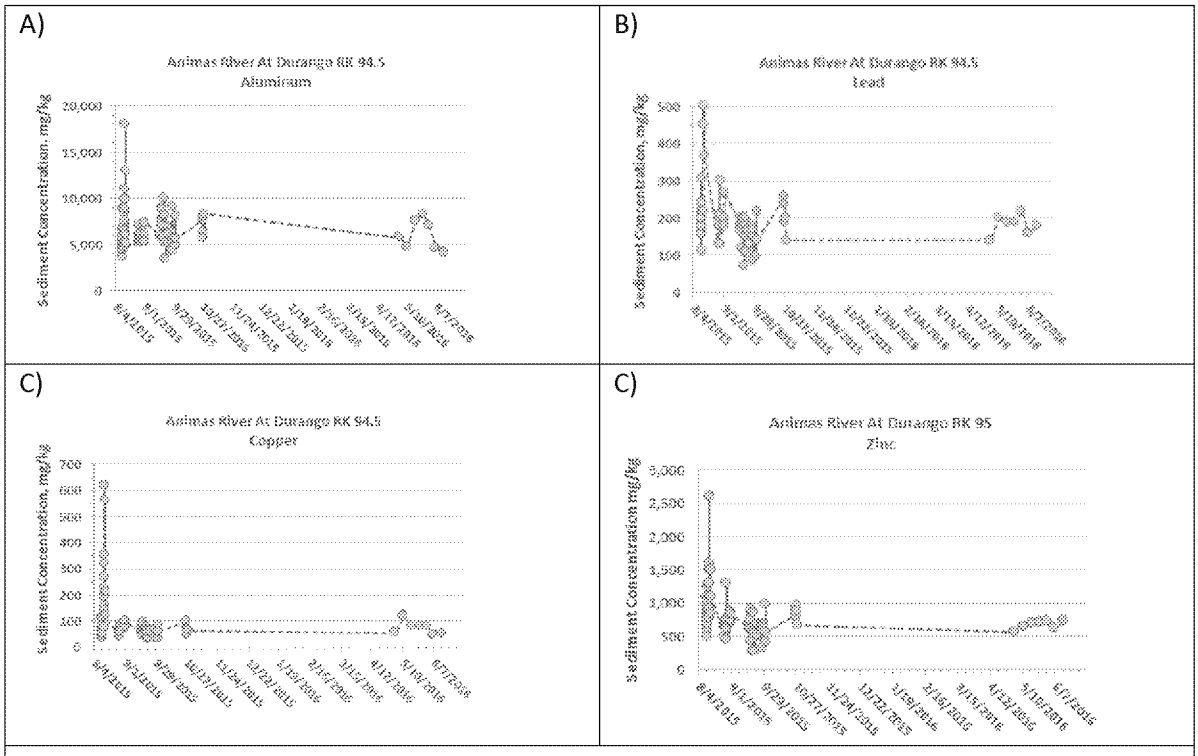


Figure 8-21. Sediment concentration of samples collected in the Animas River at RK 96.6 from 8/5/2015 to 6/30/2016 sequenced in time in mg/kg. (A) Aluminum, (B) Lead, (C) Copper, and (D) Zinc. 2016 snowmelt data are included.

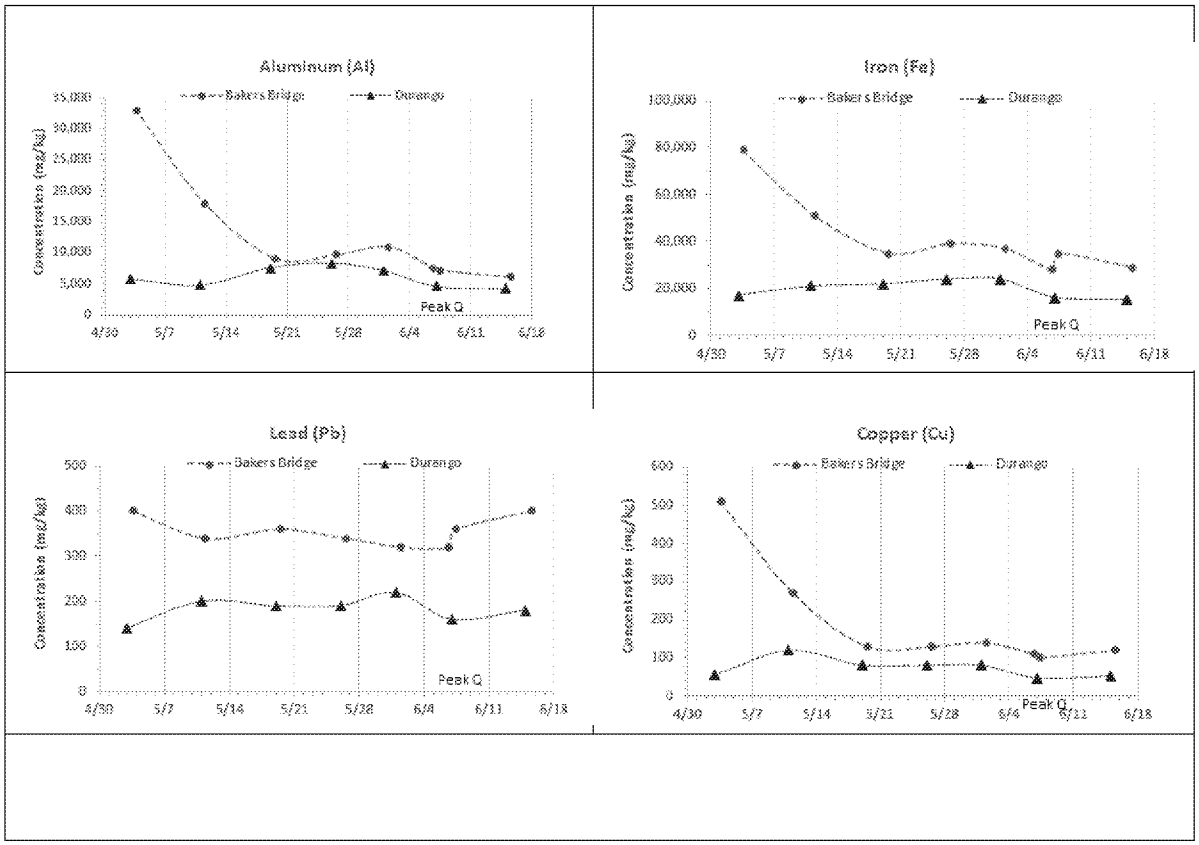


Figure 8-22. Sequence of sediment samples collected during 2016 snowmelt for 4 metals comparing the Animas River at RK 64.0 (Bakers Bridge) and RK 94.2 (Durango).

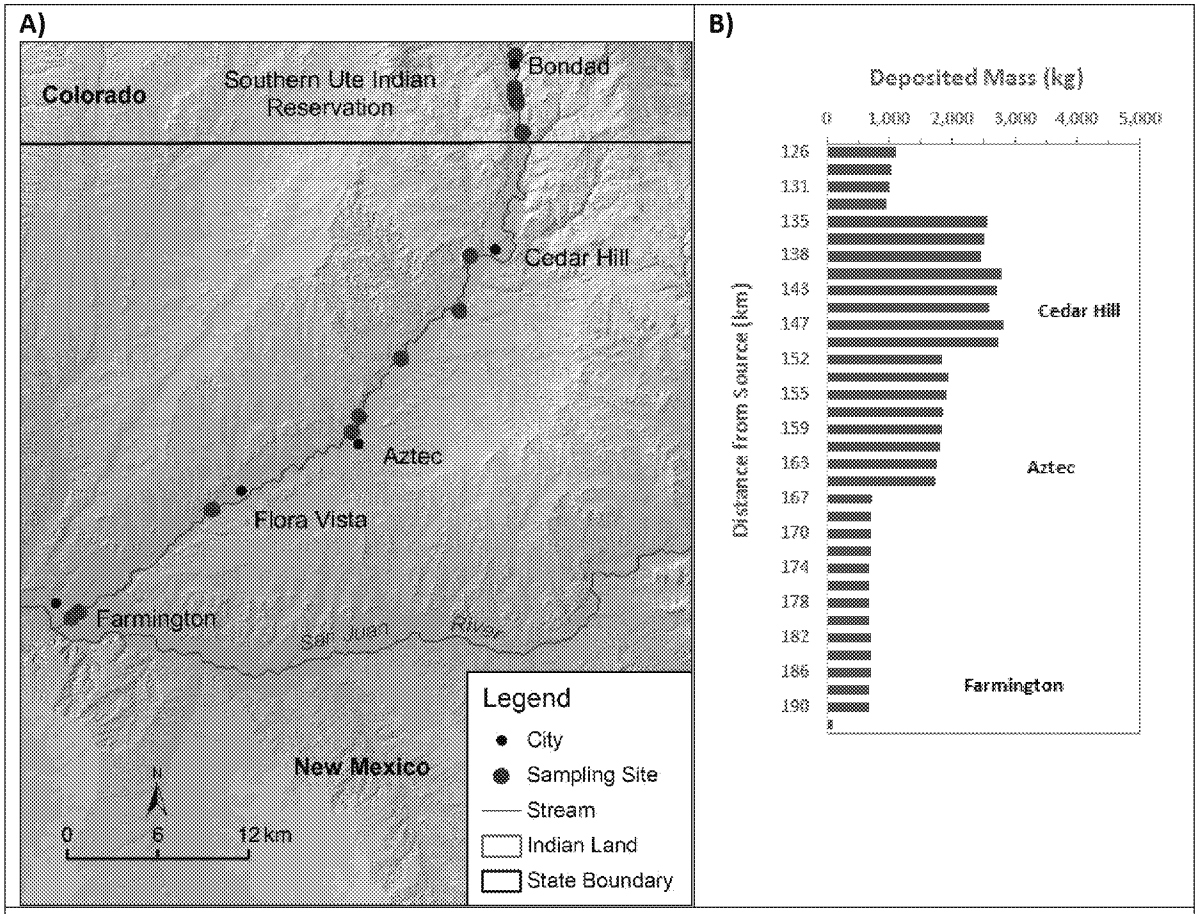


Figure 8-23. Location map of the lower Animas River Segment. Lower reach of the Animas River from approximately RK 132 to RK 191 at the confluence of the Animas and San Juan Rivers in Farmington (A). Sampling locations are shown as red dots. Mass deposits estimated with WASP modeling in approximately 2-km segments through the middle Animas reach as an indicator of localized deposition zones (B).

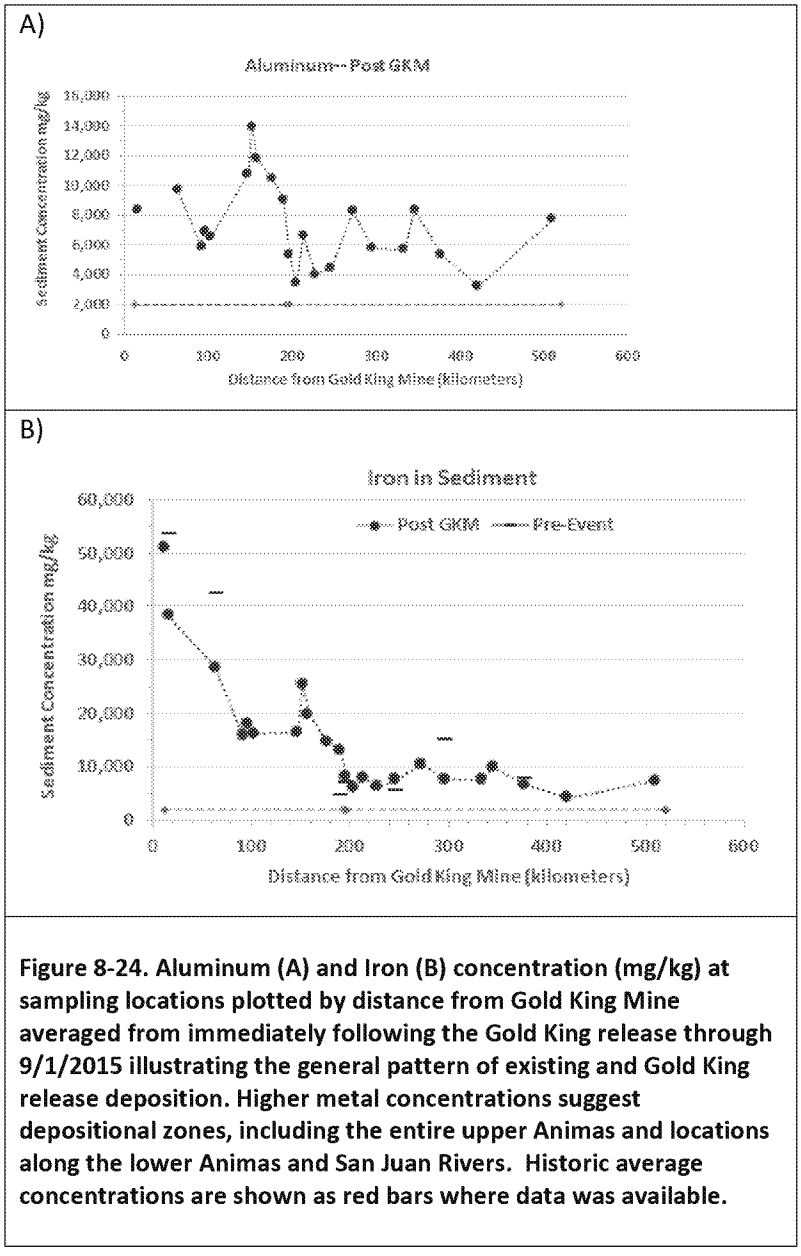


Figure 8-24. Aluminum (A) and Iron (B) concentration (mg/kg) at sampling locations plotted by distance from Gold King Mine averaged from immediately following the Gold King release through 9/1/2015 illustrating the general pattern of existing and Gold King release deposition. Higher metal concentrations suggest depositional zones, including the entire upper Animas and locations along the lower Animas and San Juan Rivers. Historic average concentrations are shown as red bars where data was available.

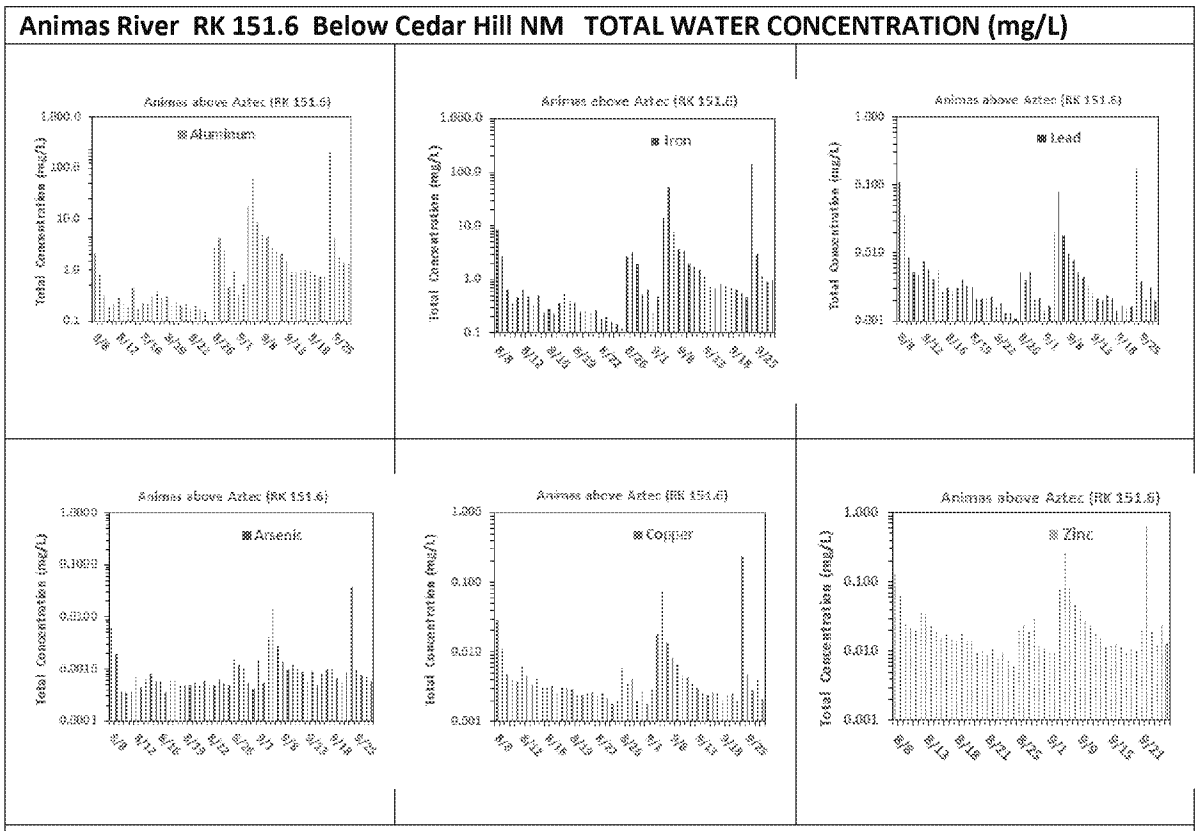


Figure 8-25. Total water concentration of samples collected from the Animas River at RK 151.6 between 8/5/2015 and 6/30/2016 sequenced in time in mg/L. The last sample shown was collected during snowmelt in June 2016. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. The Gold King plume was clearly evident at many locations but sampling began after the peak plume. The data presentation is intended to emphasize post release trends.

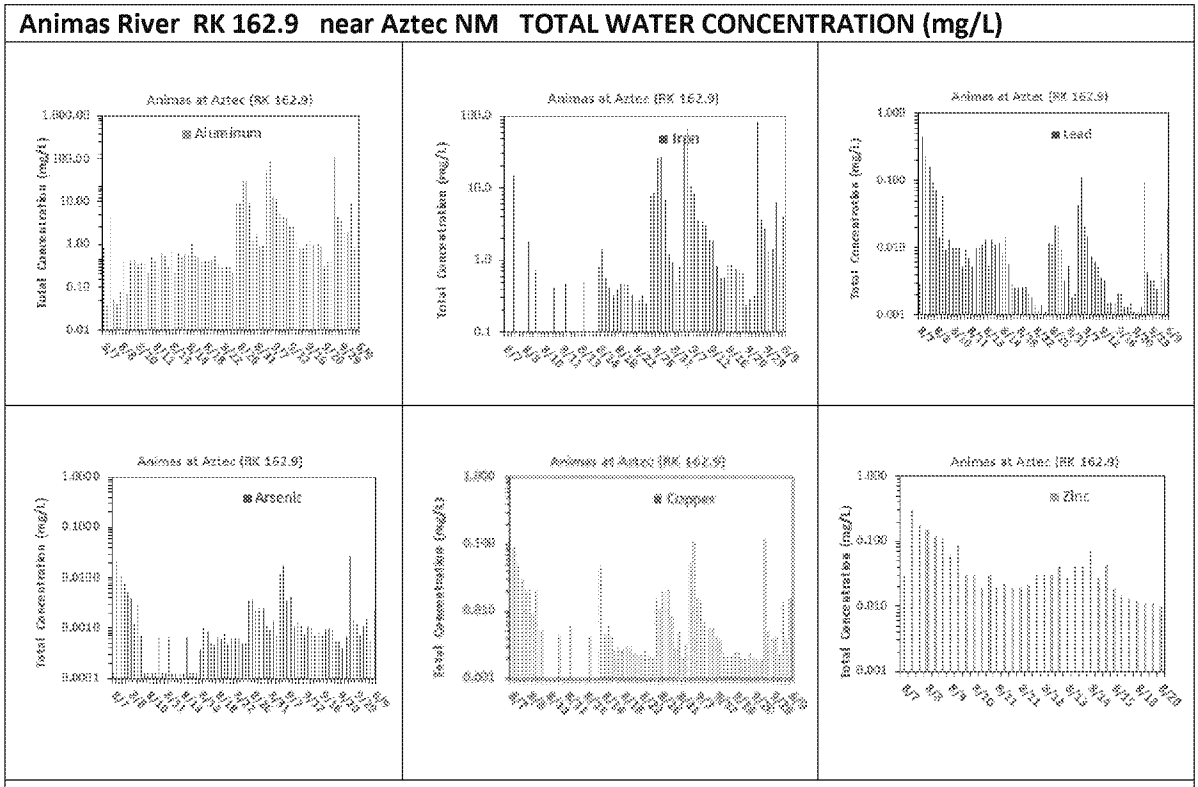


Figure 8-26. Total water concentration of samples collected from the Animas River at RK 162.9 between 8/5/2015 and 6/30/2016 sequenced in time in mg/L. The last sample shown was collected during snowmelt in June 2016. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. The Gold King plume was clearly evident at many locations but sampling began after the peak of the plume. The data presentation is intended to emphasize post release trends.

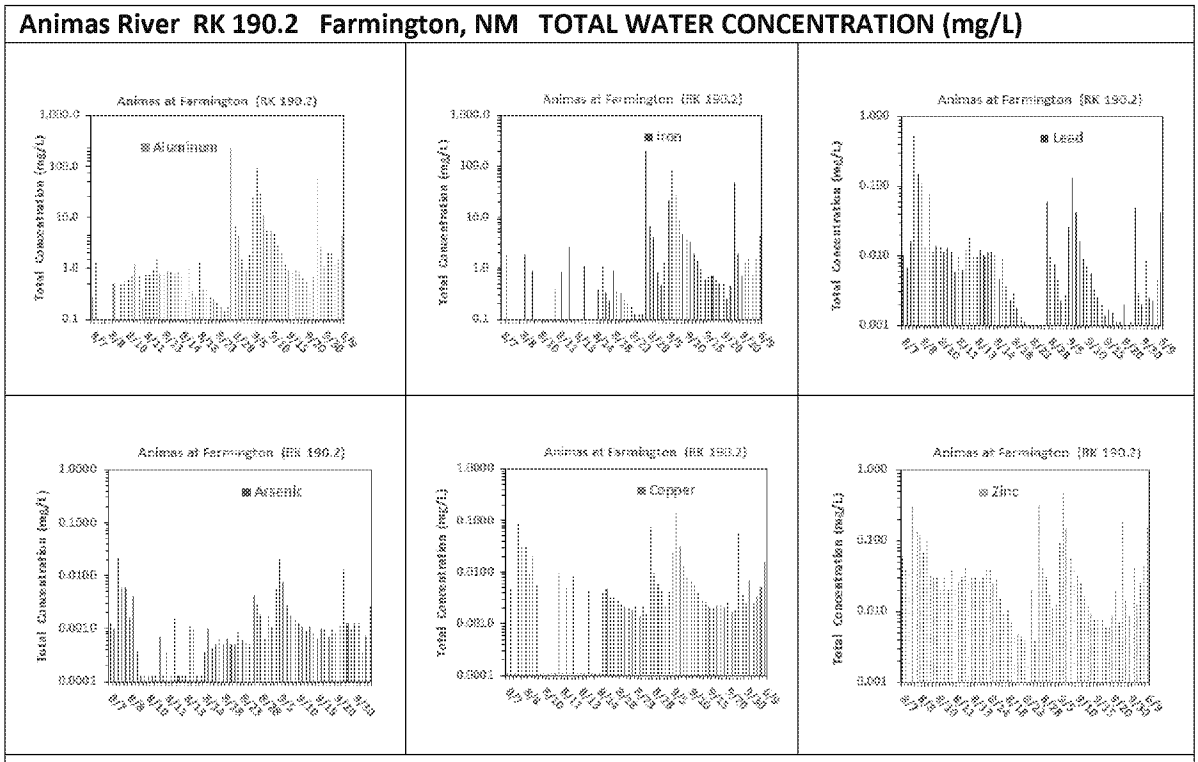


Figure 8-27. Total water concentration of samples collected from the Animas River at RK 190.2 between 8/5/2015 and 6/30/2016 sequenced in time in mg/L. The last sample shown was collected during snowmelt in June 2016. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. The Gold King plume was clearly evident at many locations but sampling began after the peak of the plume. The data presentation is intended to emphasize post release trends.

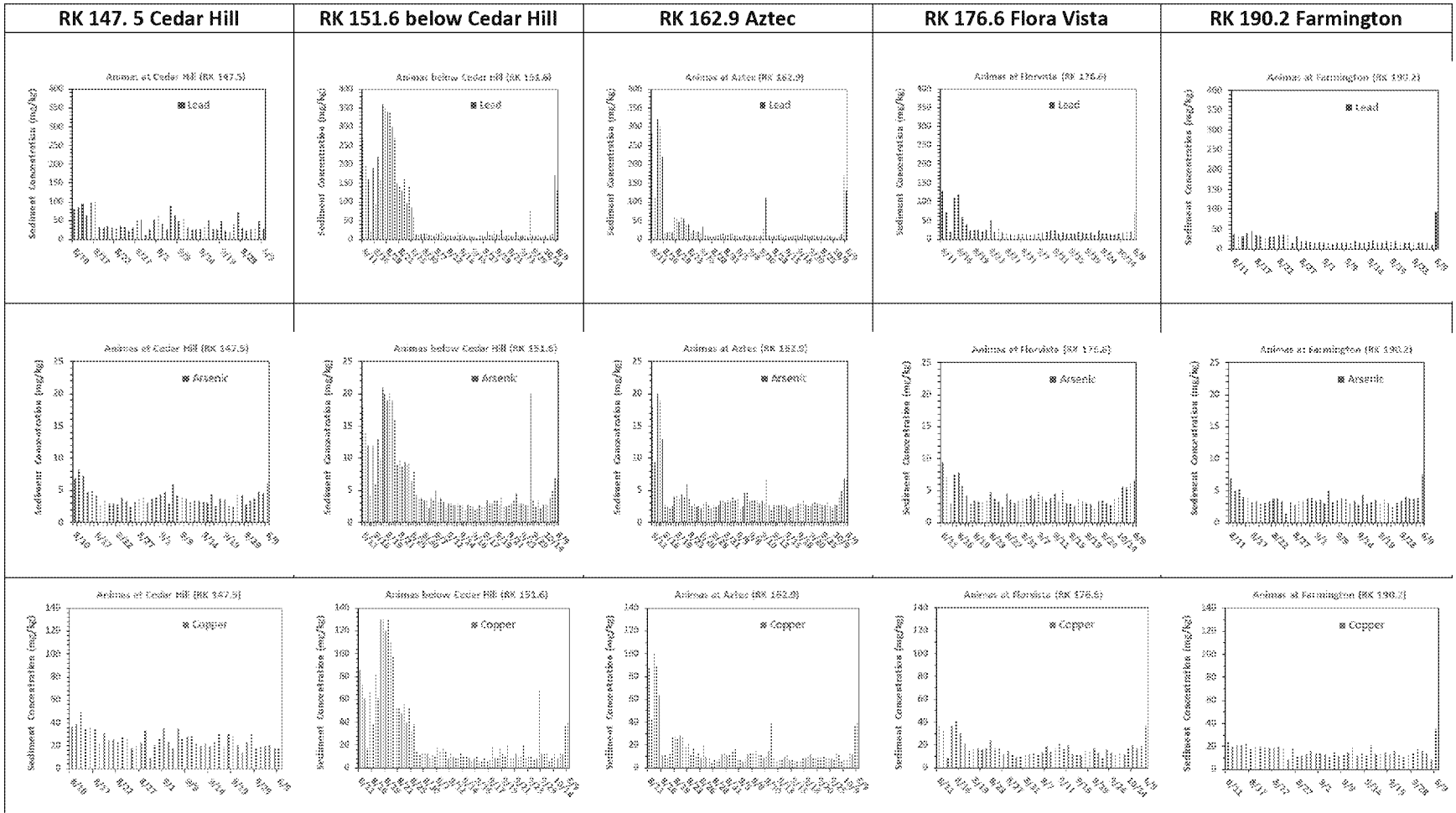


Figure 8-28. Sediment concentration of samples collected from the Animas River at five locations from RK 147.5 to RK 190.2 from 8/5/2015 and 6/30/2016 sequenced in time in mg/kg. The last sample shown was collected during snowmelt in June 2016. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day.

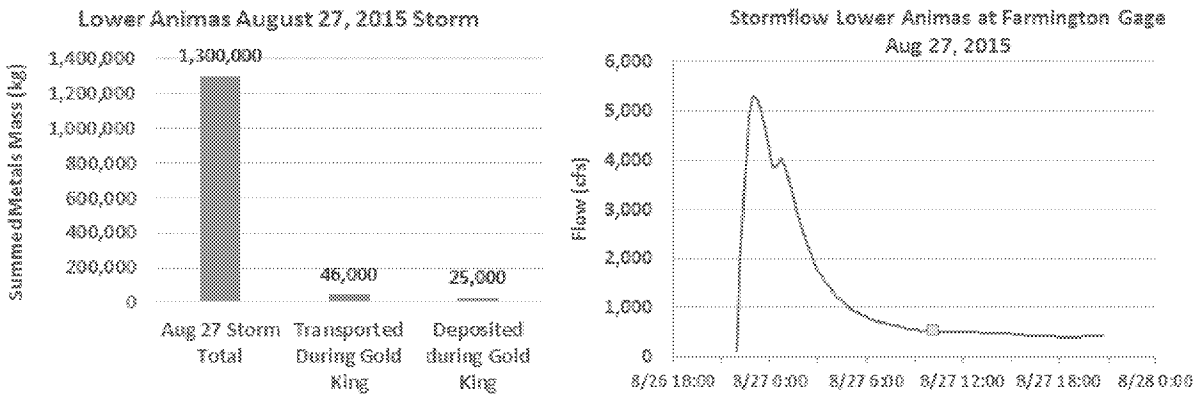


Figure 8-29. Lower Animas storm in August 2015 with sampling time plotted. Summed total metals mass transported in the lower Animas River at Farmington during the storm event on August 27 three weeks after passage of the Gold King plume. A minimum estimate of mass of 1,300,000 kg far surpassed the mass carried during the plume and deposited within the reach that experienced the storm. The storm only affected the lower Animas below river kilometer 164 and was the first storm to potentially mobilize deposits. Only one sample was collected during this largely nighttime event.

Table 8-8. Results of statistical analyses comparing pre-event to post-event dissolved metal concentrations at sites on the Animas River at RK 190.2 (Farmington, NM). Total metal concentrations were not measured in the pre-event period at Farmington. In the post-event period samples were included from flow between 250 and 500 cfs.

Dissolved Concentration	Animas River at Farmington					
Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	10	2.9	126	306	0.0002	0.0004
Cadmium	0.05	0.01	0.11	0.06	0.15	0.27
Copper	2.52	1.1	2.49	0.34	0.97	0.97
Iron	7	1.4	78	220	0.0003	0.001
Lead	0.22	0.30	0.34	0.40	0.53	0.52
Manganese	31	17	28	10	0.85	0.59
Zinc	12	14	5	1.4	0.14	0.11
n=	9		16			

Bed Sediment Concentration	Animas River at Farmington					
Metal	Pre-Event (mg/kg)	SE	Fall 2015 (mg/kg)	SE	t-test p-value	Wilcoxon p-value
Aluminum	Not Measured	-	9800	479	-	-
Cadmium	1.1	0.70	0.2	0.02	0.022	0.001
Copper	8.6	3.2	15	0.58	0.47	0.57
Iron	4476	2807	13300	381	0.18	0.12
Lead	23	7.5	21	1.3	0.31	0.34
Manganese	318	145	420	12	0.72	0.51
Zinc	89	68	93	6.0	0.41	0.19
n=	6		46			

Bed Sediment Concentration	Animas River at Farmington			
Metal	Pre-Event (mg/kg)	SE	2016 Snowmelt (mg/kg)	z-score
Aluminum	Not Measured	-	9500	-
Cadmium	1.1	0.7	0.88	-0.11
Copper	8.6	3.2	35	3.4
Iron	4476	2807	17000	1.8
Lead	23	7.5	94	3.9
Manganese	318	145	840	1.5
Zinc	89	68	350	1.6
n=	6		1	

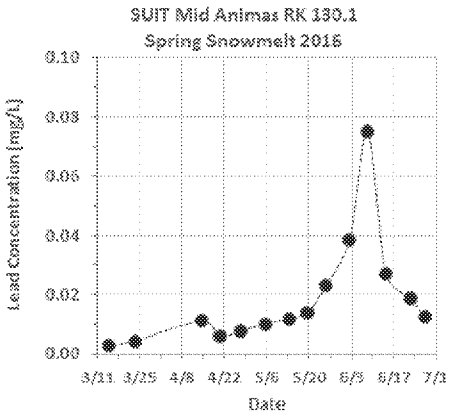
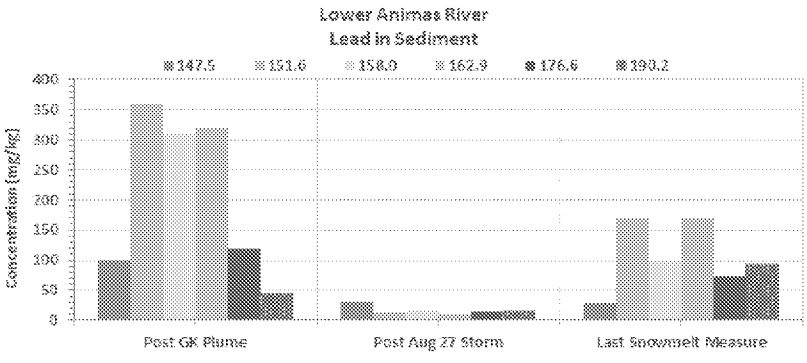


Figure 8-30. Total concentration of lead in water (mg/L) during the 2016 snowmelt hydrograph at RK 130.1 on the Animas River as it passes through the Southern Ute Indian Tribe reservation south of Durango, CO.



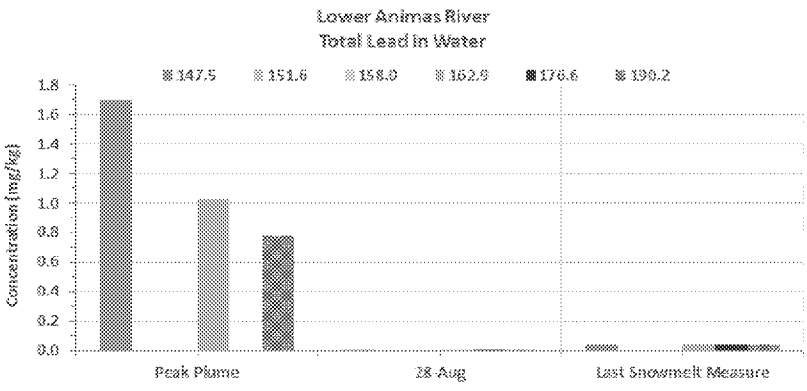
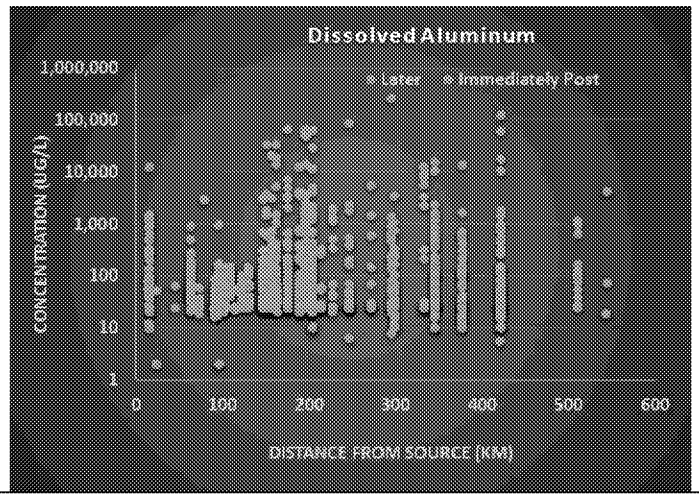
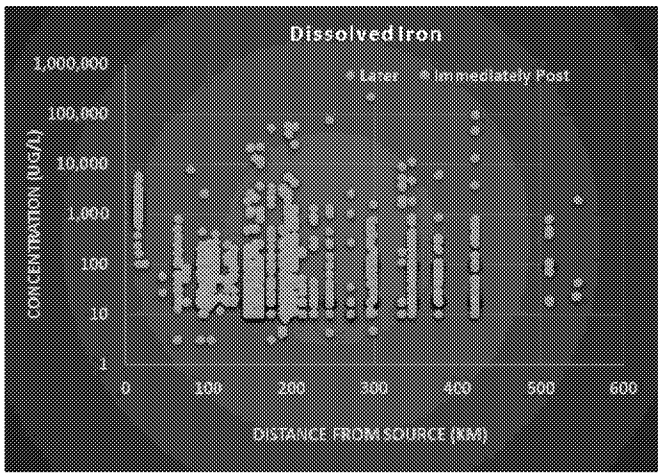
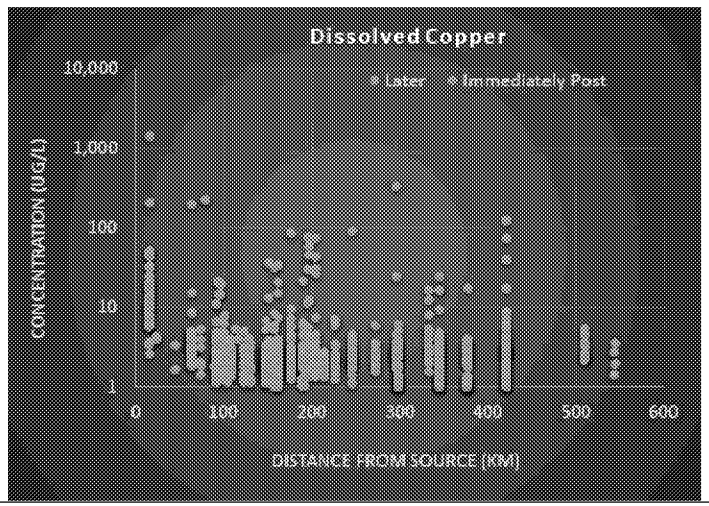


Figure 8-31. Comparison of total water concentrations (A) and sediment concentrations (B) of lead at sites within the lower Animas River during key periods. Data during plume was the maximum observed concentration during the time when the Gold King plume passed within a one week period. August 28 represents the day following the large storm on 8/27/2015. Snowmelt was sampled once in June near the peak of the snowmelt hydrograph.







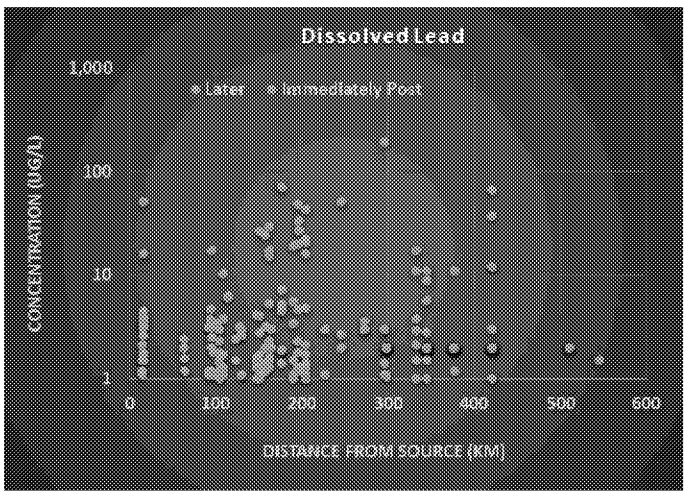


Figure 8-32. Dissolved concentrations at sites plotted in relation to distance from Gold King. Orange points are immediately post Gold King release taken as August 5 to August 19. Later are post this date, with most samples collected before November 2015.

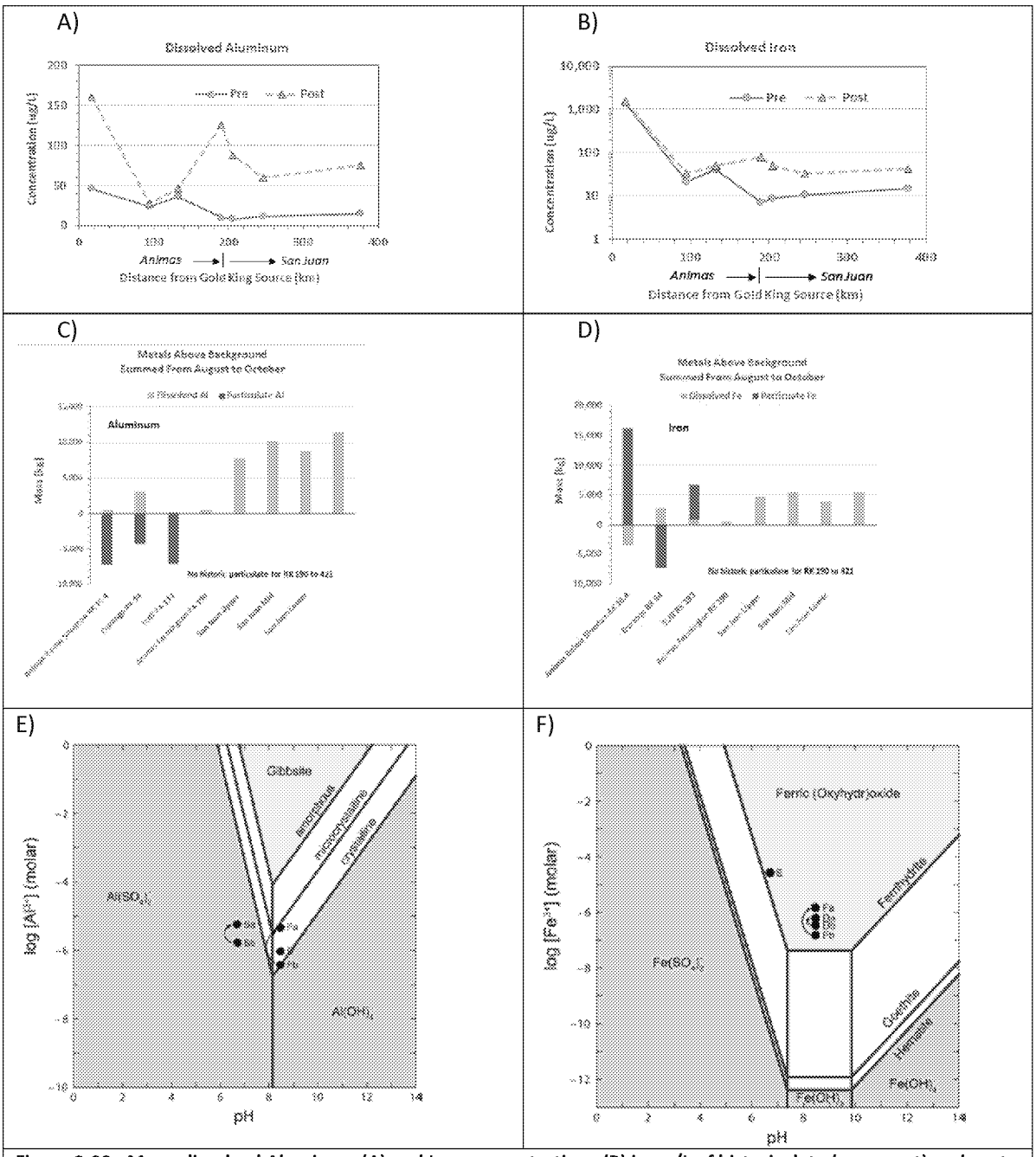


Figure 8-33. Mean dissolved Aluminum (A) and Iron concentrations (B) in ug/L of historic data (pre-event) and post-event. Means are plotted longitudinally along the Animas and San Juan Rivers plotted where pre-event data was available. Means were taken from the statistical tables (Tables 8-3 to 8-10). Mean concentrations are translated to mass (kg) by multiplying the average concentration at each location by taking the average flow at the nearest USGS station for a period of 60 days. C) Stability fields of (A) aluminum oxide minerals as a function of [Al^{3+}] and pH, with [$SO_4^{=}$] = 90 mg/l, similar to conditions expected in the upper Anima; and (B) ferric oxide minerals as a function of [Fe^{3+}] and pH, with [$SO_4^{=}$] = 90 mg/l, similar to conditions expected in the upper Animas. Thermodynamic data for Al as reported in Nordstrom et al. (Nordstrom et al. 1984) with additional data from Geochemist's Workbench (Bethke 1998). See Appendix C for more discussion. Al and Fe minerals with three locations in the Animas designated by their first letters, and before and after by 'b' and 'a' respectively. After Steefel, C. I. and P. V. van Cappellen (1990).

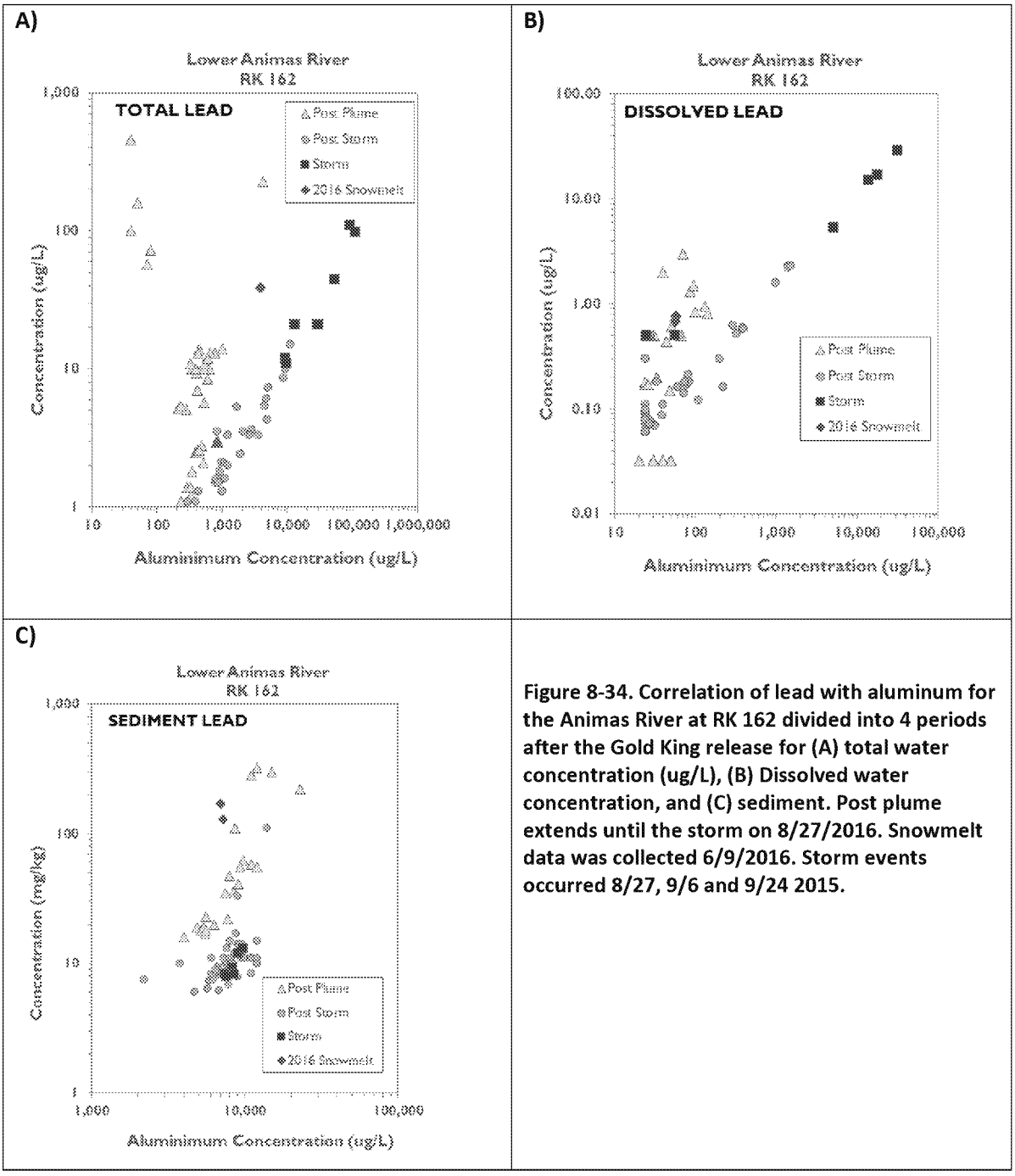


Figure 8-34. Correlation of lead with aluminum for the Animas River at RK 162 divided into 4 periods after the Gold King release for (A) total water concentration (ug/L), (B) Dissolved water concentration, and (C) sediment. Post plume extends until the storm on 8/27/2016. Snowmelt data was collected 6/9/2016. Storm events occurred 8/27, 9/6 and 9/24 2015.

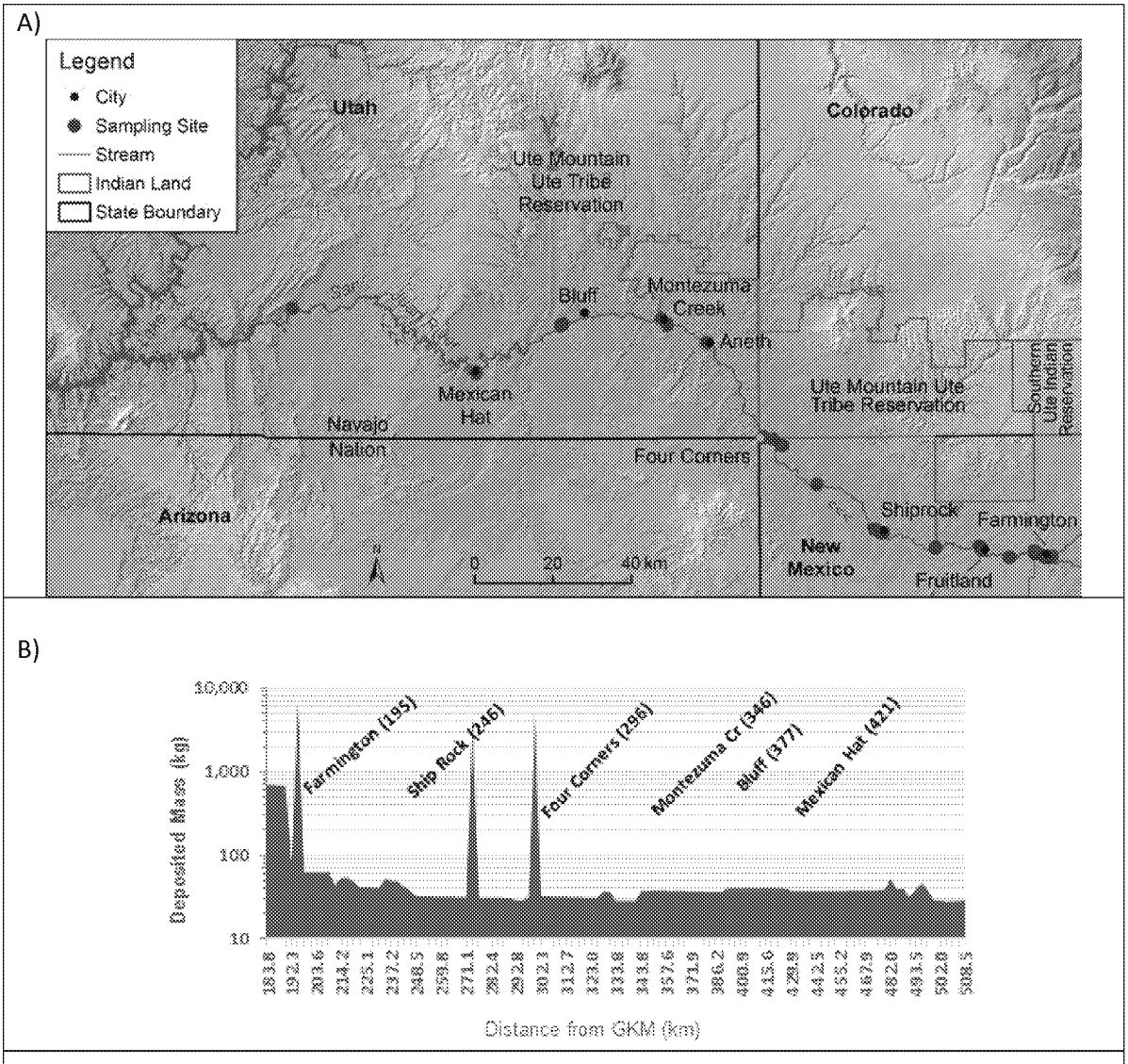


Figure 8-35. San Juan River from its confluence with the Animas River at RK 191 to RK 421 (A). Sampling locations are shown as red dots. Mass deposits estimated with WASP modeling in approximately 2-km segments through the middle Animas reach as an indicator of localized deposition zones (B).

SAN JUAN River RK 196.9 Farmington, NM TOTAL WATER CONCENTRATION (mg/L)

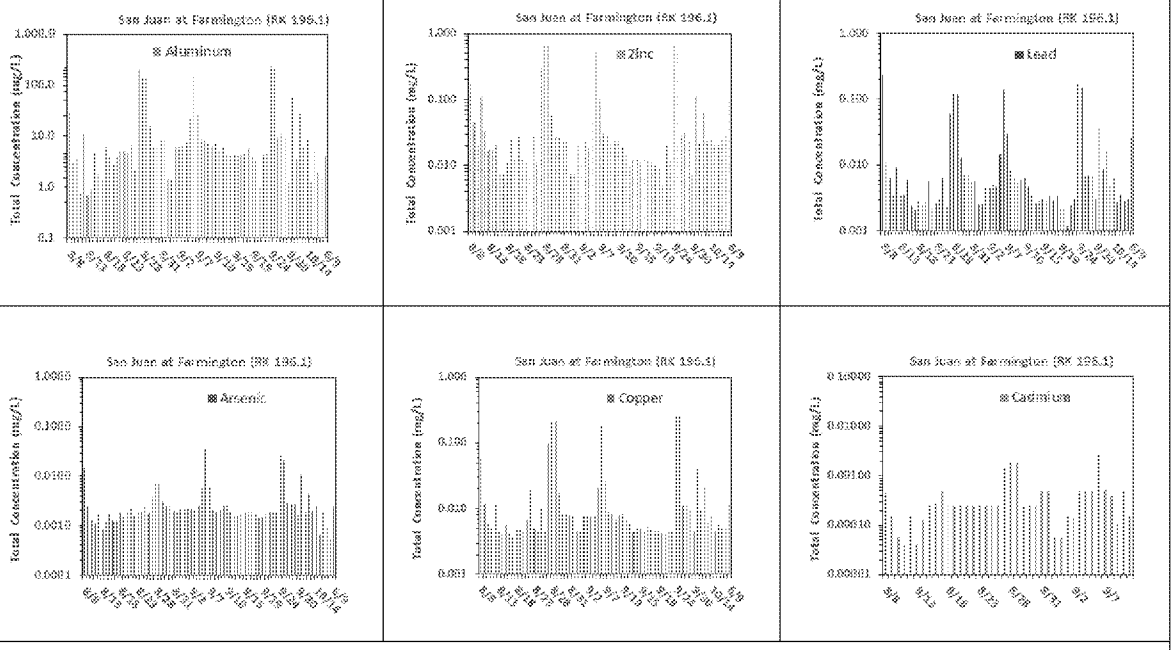


Figure 8-36. Total water concentration of samples collected from the San Juan River at RK 196.1 below the confluence with Animas River in Farmington between 8/5/2015 and 6/30/2016 sequenced in time in mg/L. The last data point was collected during snowmelt in June 2016. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. The data presentation is intended to emphasize post release trends.

SAN JUAN River RK 295.8 Four Corners, CO TOTAL WATER CONCENTRATION (mg/L)

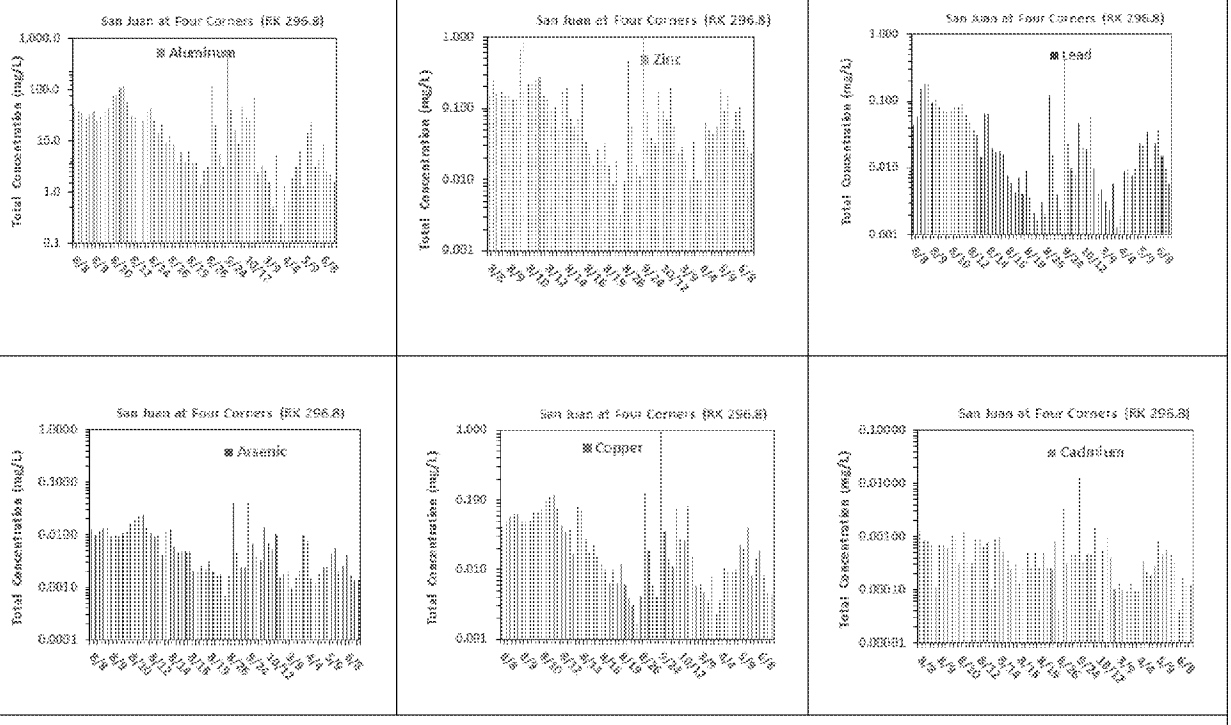


Figure 8-37. Total water concentration of samples collected from the San Juan River at RK 295.8 between 8/5/2015 and 6/30/2016 sequenced in time in mg/L. The data includes full sampling of 2016 snowmelt hydrograph. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. The data presentation is intended to emphasize post release trends.

SAN JUAN River RK 421.3 Mexican Hat UT TOTAL WATER CONCENTRATION (mg/L)

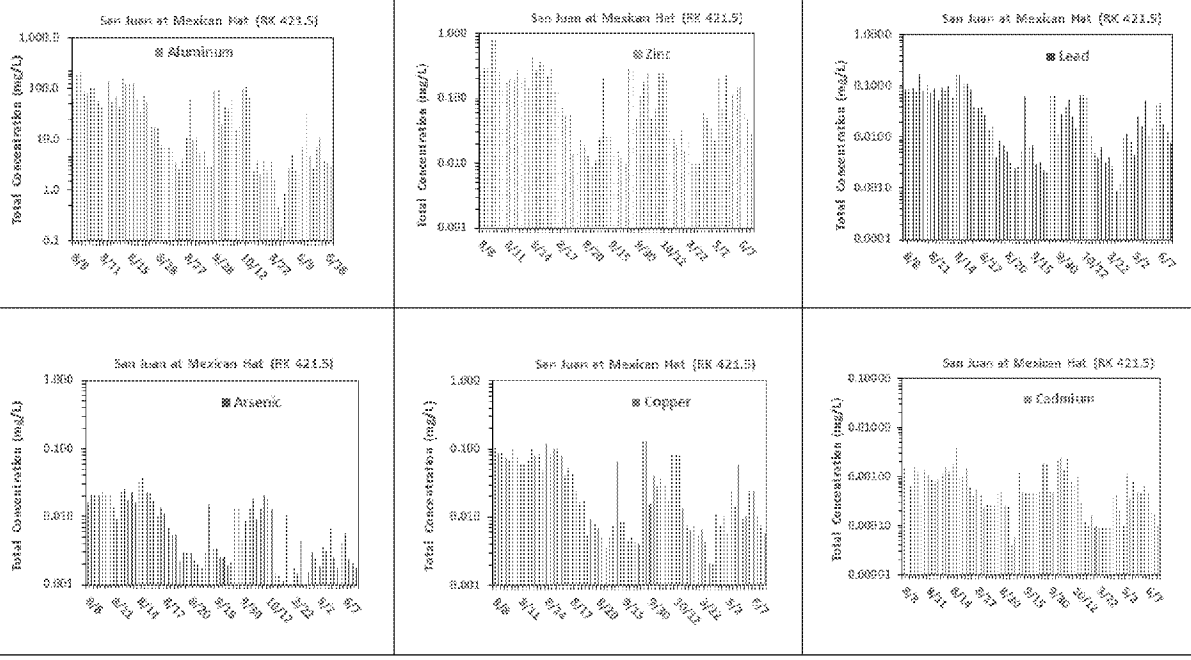


Figure 8-38. Total water concentration of samples collected from the San Juan River at RK 421.3 between 8/5/2015 and 6/30/2016 sequenced in time in mg/L. The data includes full sampling of 2016 snowmelt hydrograph. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day. Thus the X-axis scale is not uniform among sites, but are uniform for all metals shown at this location. The data presentation is intended to emphasize post release trends.

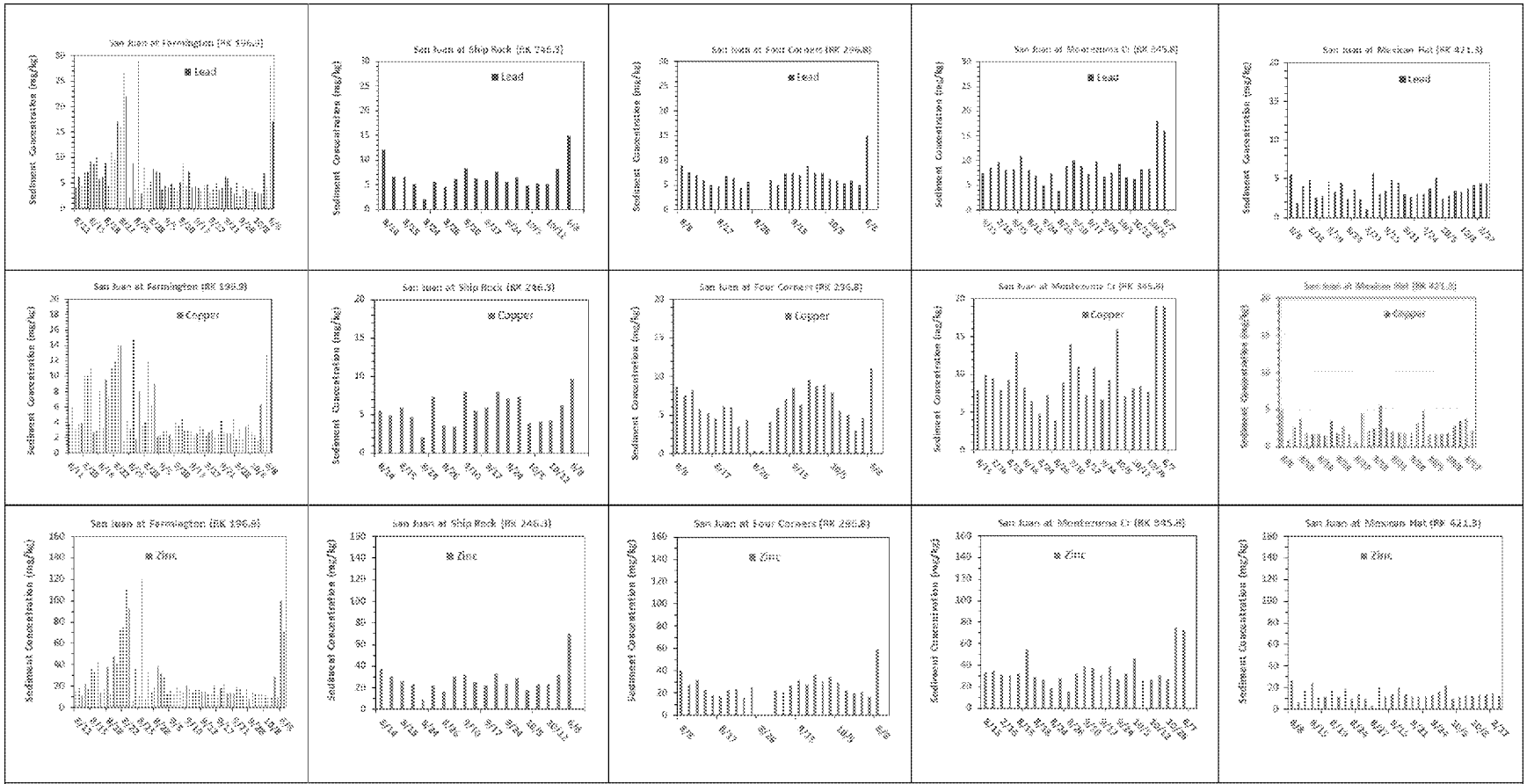


Figure 8-39. Sediment concentration of samples collected from the San Juan River at five locations from RK 196.9 to RK 421.3 from 8/5/2015 and 6/30/2016 sequenced in time in mg/kg. The last 2 samples were collected during snowmelt in June 2016. Note that dates are not uniform among sites; two samples could have been collected on the same day; some sites were measured more infrequently. Data from sites collected by multiple provides in close proximity are combined and more than one sample could be collected on the same day.

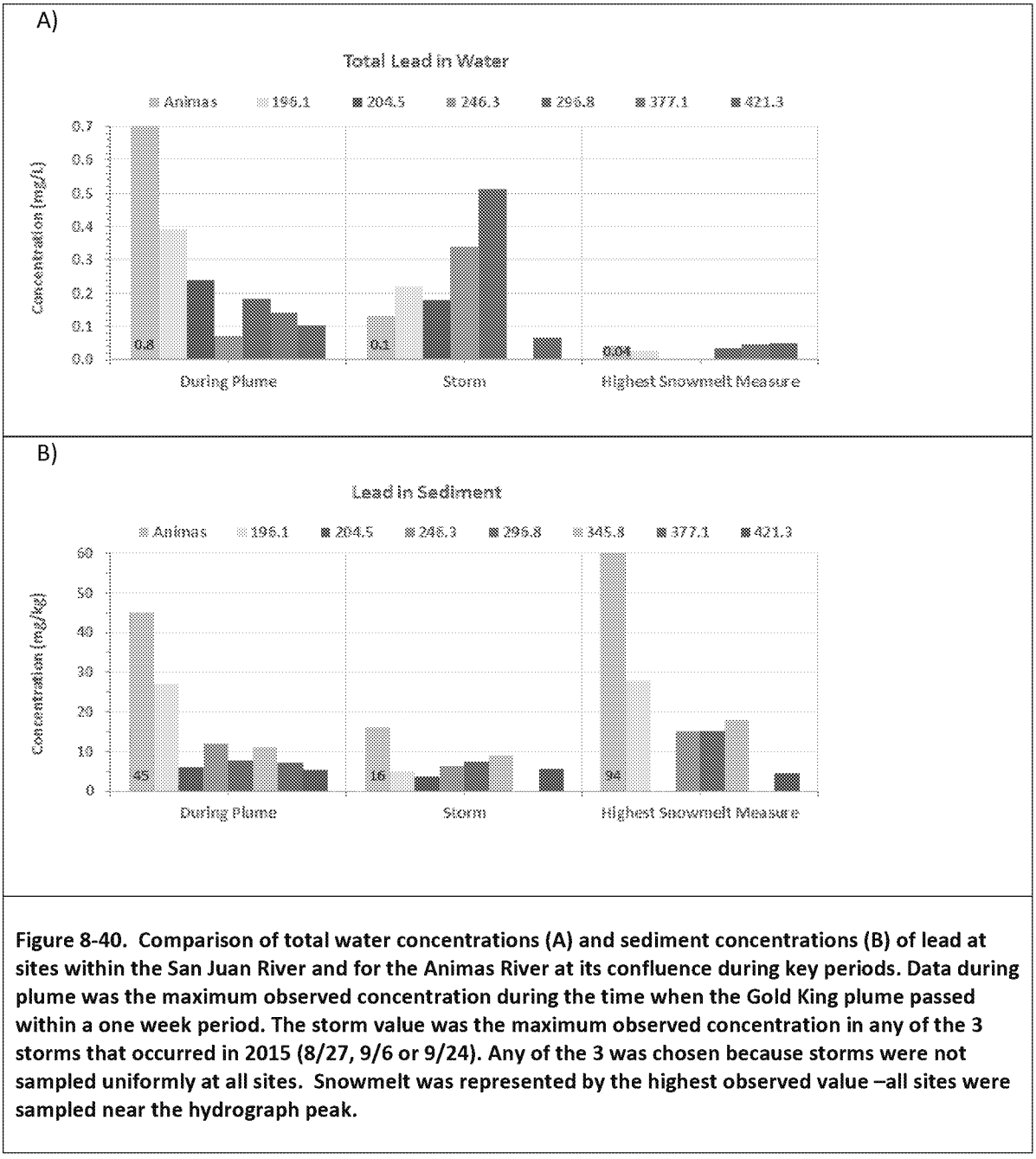


Figure 8-40. Comparison of total water concentrations (A) and sediment concentrations (B) of lead at sites within the San Juan River and for the Animas River at its confluence during key periods. Data during plume was the maximum observed concentration during the time when the Gold King plume passed within a one week period. The storm value was the maximum observed concentration in any of the 3 storms that occurred in 2015 (8/27, 9/6 or 9/24). Any of the 3 was chosen because storms were not sampled uniformly at all sites. Snowmelt was represented by the highest observed value –all sites were sampled near the hydrograph peak.

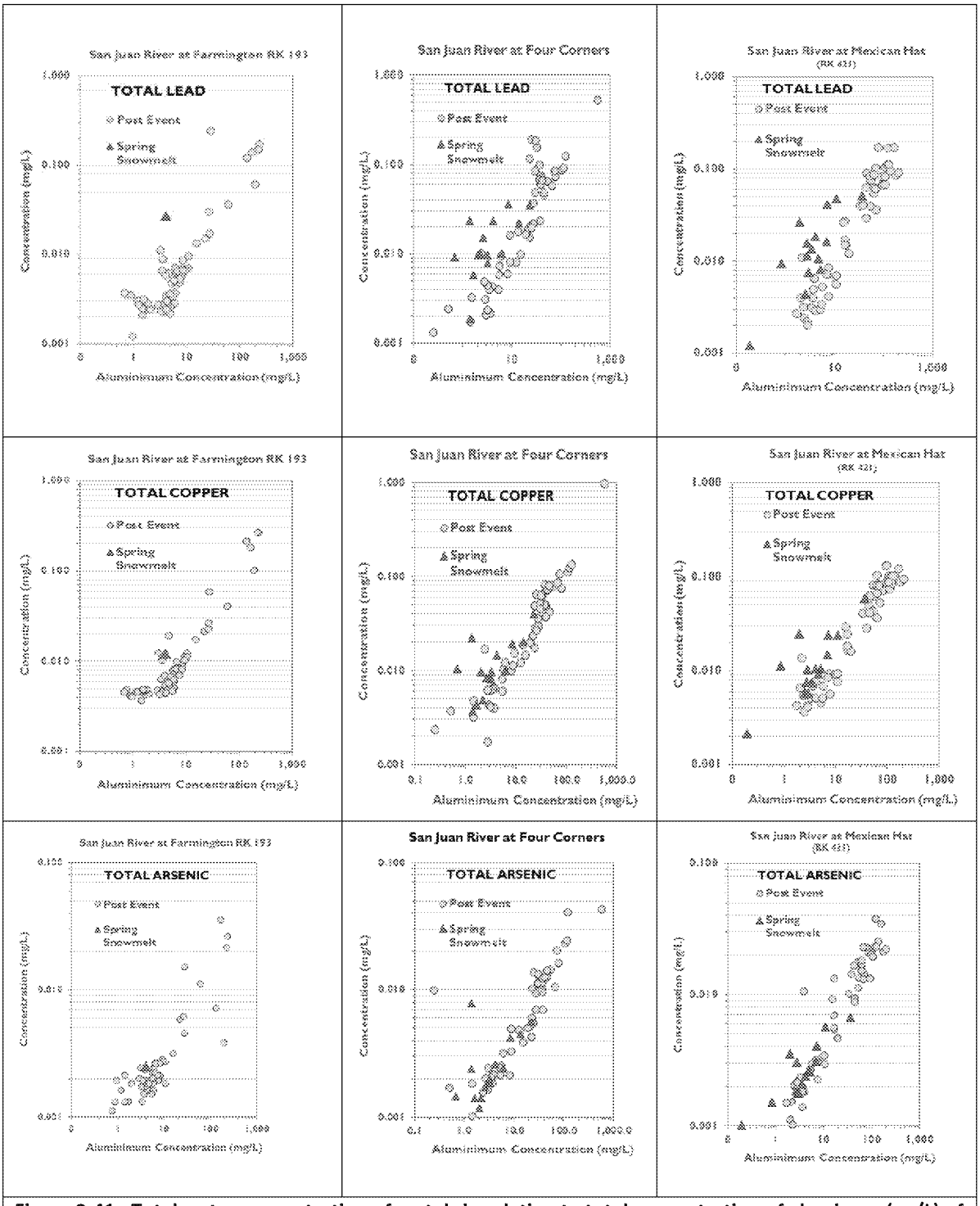


Figure 8-41. Total water concentration of metals in relation to total concentration of aluminum (ug/L) of post-event data collected from August 2015 to October 2015 (gray circles) and 2016 snowmelt data (red triangles) at two sites on the San Juan River: RK 193 (Farmington), RK 246 (Four Corners) and RK 421 (Mexican Hat).

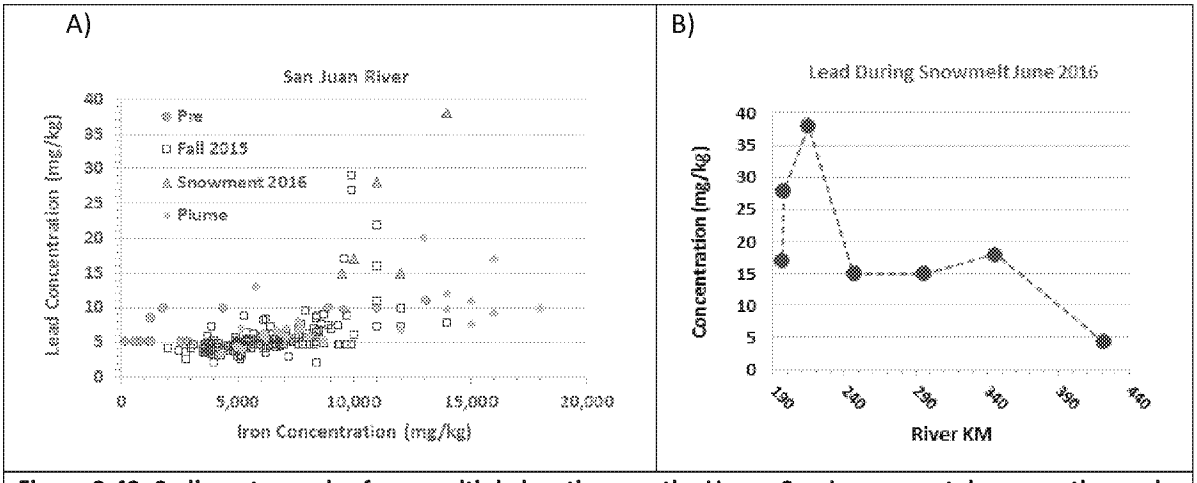


Figure 8-42. Sediment samples from multiple locations on the Upper San Juan were taken near the peak of snowmelt runoff on June 8th, 2016. Data appear to show elevated concentrations at Fruitland. Pre-event concentrations do not show a strong longitudinal pattern of bed sediment metal concentrations in the upper San Juan. The patterns seen here suggest deposits of metallic-enhanced sediment residing at Fruitland on this date.

Table 8-9. Results of statistical tests on streambed sediment metal concentrations on the upper San Juan River (Farmington to 4-Corners). Very few pre-event sediment samples existed downstream of this section of the river. Not included in testing were aluminum (not measured in pre-event samples) and cadmium (most samples below detection limits).

Bed Sediment Concentration			Upper San Juan River			
Metal	Pre-Event (mg/kg)	SE	Fall 2015 (mg/kg)	SE	t-test p-value	Wilcoxon p-value
Aluminum	Not Measured	-	3950	207	-	-
Cadmium	Predominantly Non-Detects	-	0.055	0.01	-	-
Copper	4.3	1.4	4.5	0.20	0.85	0.66
Iron	3500	1374	6300	214.2	0.004	0.005
Lead	7.1	2.7	5.6	0.28	0.03	0.004
Manganese	165	14	185	4.6	0.3	0.57
Zinc	21	2.6	20	1.2	0.94	0.18
n=	36		175			

Bed Sediment Concentration			Upper San Juan River			
Metal	Pre-Event Mean (mg/kg)	SE	Spring 2016 Mean (mg/kg)	SE	t-test p-value	Wilcoxon p-value
Aluminum	Not Measured	-	6000	848	-	-
Cadmium	Predominantly Non-Detects	-	0.26	0.06	-	-
Copper	4.3	1.4	12	2.2	0.0023	0.01
Iron	3500	1374	11200	800	0.0004	0.04
Lead	7.1	2.7	21	4.5	0.005	0.0017
Manganese	165	14	340	35	0.0003	0.0014
Zinc	21	2.6	85	16	0.0003	0.0014
n=	36		5			

Table 8-10. Results of statistical analyses comparing pre-event to post-event dissolved and total metal concentrations within various sections of the San Juan River downstream of the Animas. There were few total metal concentrations available for this analysis. Concentrations were logged (base 10) prior to testing. Analyses were divided into three regions of the river: the upper San Juan (RK 196 to 214; Farmington/Fruitland area), the middle San Juan (RK 246 to 296; Shiprock NM to Four Corners CO) and the lower San Juan (RK 345 to RK 421; Montezuma Cr to Mexican Hat UT). Flow in the post-event period varied between 500 and 1130 cfs. There were had 117-154 samples spread out across the three regions in the post-event period, and 50-100 samples across the three regions in the pre-event period.

Dissolved Metal Concentration — Upper San Juan River RK 193 - RK 214

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	8.3	1.6	87.1	55	<0.0001	<0.0001
Cadmium	0.31	0.04	0.47	0.01	Non-Detection Bias	
Copper	1.5	0.19	2.2	0.11	Non-Detection Bias	
Iron	8.9	0.49	50.1	34	<0.0001	<0.0001
Lead	0.14	0.03	0.19	0.06	Non-Detection Bias	
Manganese	14.1	1.5	10.5	27	0.11	0.007
Zinc	4.3	0.23	3.2	0.29	Non-Detection Bias	
***n=**	**35***	**60**	***n variable among metals**			

Dissolved Metal Concentration — Middle San Juan River RK 215 - RK 297

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	11.7	142	60.3	49.8	<0.0001	<0.0001
Cadmium	0.38	0.05	0.50	0.00	Non-Detection Bias	
Copper	2.1	0.25	2.4	0.17	Non-Detection Bias	
Iron	10.5	0.89	32.4	31	0.00036	0.0018
Lead	0.17	0.14	0.15	0.05	Non-Detection Bias	
Manganese	4.3	1.9	4.7	1.5	0.023	0.04
Zinc	4.1	0.47	3.8	0.58	Non-Detection Bias	
n=	**51***	**29**	***n variable among metals**			

Dissolved Metal Concentration — Lower San Juan River RK 296 - RK 421

Metal	Pre (ug/l)	SE	Post (ug/l)	SE	t-test p-value	Wilcoxon p-value
Aluminum	15.1	10	75.9	287	<0.0001	<0.0001
Cadmium	0.52	0.08	0.50	0.00	Non-Detection Bias	
Copper	4.0	0.28	2.8	0.26	Non-Detection Bias	
Iron	14.8	8.6	43.1	308.1	0.00027	<0.0001
Lead	0.15	0.06	0.20	0.27	Non-Detection Bias	
Manganese	4.6	2.7	3.0	4.8	0.04	0.02
Zinc	5.1	1.1	5.2	1.1	Non-Detection Bias	
n=	**51***	**65**	***n variable among metals**			

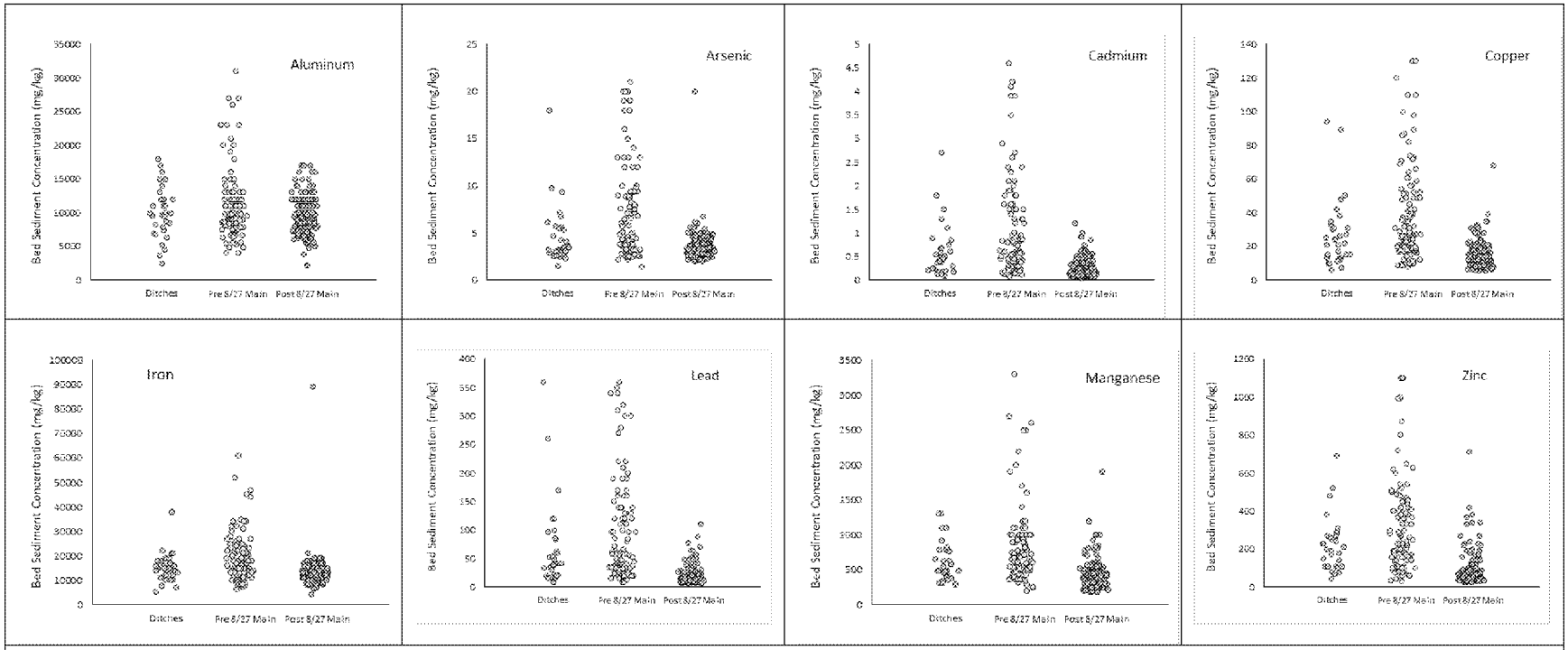


Figure 8-43. Distribution of sediment concentrations in samples collected from irrigation ditches drawing water from the lower Animas River from RK 135 to 190 km. Sediment metal concentration (mg/kg) from samples taken from various sites within the mainstem of the Animas River (135-190km; samples taken before 8/27 are yellow dots, after 8/27 are blue dots) to metal concentrations in sediment samples from ditches in the same area (green dots; samples taken on 8/13 and 8/14). Samples from the river collected prior to the 8/27 storm ranged over a wide range with some elevated in most metals. Samples taken after 8/27 show lower concentrations, except for a single outlier. Metals in the river were significantly less after the large storm on 8/27 removed deposits and was probably more representative of pre-event conditions. Ditch samples generally were within the same range as later samples, but there appeared to be some elevated samples for some metals suggesting some contamination.